EXHIBIT A

EXPERT REPORT OF JOWEI CHEN, Ph.D.

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I am an Associate Professor in the Department of Political Science at the University of Michigan, Ann Arbor. I am also a Faculty Associate at the Center for Political Studies of the Institute for Social Research at the University of Michigan as well as a Research Associate at the Spatial Social Science Laboratory at Stanford University. In 2007, I received a M.S. in Statistics from Stanford University, and in 2009, I received a Ph.D. in political science from Stanford University. I have published academic papers on legislative districting and political geography in several political science journals, including *The American Journal of Political Science* and *The American Political Science Review*, and *Election Law Journal*. My academic areas of expertise include legislative elections, spatial statistics, geographic information systems (GIS) data, redistricting, racial politics, legislatures, and political geography. I have unique expertise in the use of computer simulations of legislative districting and to study questions related to political geography and redistricting.

I have provided expert reports in the following redistricting court cases: Missouri National Association for the Advancement of Colored People v. Ferguson-Florissant School District and St. Louis County Board of Election Commissioners (E.D. Mo. 2014); Rene Romo et al. v. Ken Detzner et al. (Fla. 2d Judicial Cir. Leon Cnty. 2013); The League of Women Voters of Florida et al. v. Ken Detzner et al. (Fla. 2d Judicial Cir. Leon Cnty. 2012); Raleigh Wake Citizens Association et al. v. Wake County Board of Elections (E.D.N.C. 2015); Corrine Brown et al. v. Ken Detzner et al. (N.D. Fla. 2015); City of Greensboro et al. v. Guilford County Board of Elections, (M.D.N.C. 2015); Common Cause et al. v. Robert A. Rucho et al. (M.D.N.C. 2016); League of Women Voters of Pennsylvania et al. v. Commonwealth of Pennsylvania et al. (No. 261 M.D. 2017); Georgia State Conference of the NAACP et al v. The State of Georgia et al. (N.D. Ga. 2017). I have testified at trial in the following cases: Raleigh Wake Citizens Association et al. v. Wake County Board of Elections (E.D.N.C. 2015); City of Greensboro et al. v. Guilford County Board of Elections (M.D.N.C. 2015); Common Cause et al. v. Robert A. Rucho et al. (M.D.N.C. 2016); League of Women Voters of Pennsylvania et al. v. Commonwealth of Pennsylvania et al. (No. 261 M.D. 2017). I am being compensated $500 per hour for my work in this case.

Research Questions and Summary of Findings:

The attorneys for the Plaintiffs in this case have asked me to analyze Michigan's current House, Senate, and Congressional districting plans, as created by Public Act 128 of 2011 and Public Act 129 of 2011. Specifically, I was asked to analyze whether each of these three enacted districting plans has the effect of producing an extreme partisan outcome that diverges from possible alternative maps.[1]

In conducting my academic research on legislative districting, partisan and racial gerrymandering, and electoral bias, I have developed various computer simulation programming techniques that allow me to produce a large number of non-partisan districting plans that adhere to traditional districting criteria using US Census geographies as building blocks. This simulation process is non-partisan in the sense that the computer ignores all partisan and racial considerations when drawing districts. Instead, the computer simulations are programmed to optimize districts with respect to various traditional districting goals, such as equalizing population, maximizing geographic compactness, and preserving county, municipal, and ward boundaries. By generating a large number of randomly drawn districting plans that closely follow and optimize on these traditional districting criteria, I am able to assess any enacted plan drawn by a state legislature and determine whether the enacted plan produces a partisan outcome that deviates from computer-simulated plans that follow traditional, partisan-neutral districting criteria.

More specifically, by holding constant the application of non-partisan, traditional districting criteria through the simulations, I am able to determine whether the enacted plans were partisan outliers.

I used this simulation approach to analyze Michigan's enacted House, Senate, and Congressional districting plans in several ways. First, I conducted 3,000 independent simulations, instructing the computer to generate 1,000 House, 1,000 Senate, and 1,000 Congressional districting plans for Michigan that strictly follow the non-partisan districting outlined in Act 463 of 1996 and Act 221 of 1999 and are reasonably geographically compact. I found that all 1,000 computer-simulated plans contain fewer county breaks and fewer municipal

[1] I reviewed Michigan's statutory redistricting guidelines in MCL § 3.63 et seq and MCL § 4.261 et seq and applied the criteria mandated in these statutes to produce a set of alternative maps for Michigan's Congressional, Senate, and House districting plans.

breaks than are contained in Michigan's enacted plan. The enacted plans' districts are also significantly more geographically non-compact than every single one of the 1,000 computer-simulated districting plans created for Michigan's House, Senate, and Congressional delegation.

Most importantly, I found that each of the enacted plans was a partisan outlier when compared to the computer-simulated plans. Each of the three enacted plans creates more Republican districts than every single one of the 1,000 computer-simulated districting plans created for Michigan's House, Senate, and Congressional delegation. Using common quantitative measures of political bias, including the Efficiency Gap and the Median-Mean Difference, every one of the computer-simulated plans is more politically neutral than Michigan's enacted Congressional, Senate, and House plans.

Michigan's Statutory Redistricting Guidelines
And the Computer-Simulated Districting Algorithm

Michigan has two redistricting statutes - MCL § 4.261 et seq (Act 463 of 1996) and MCL § 3.63 et seq (Act 221 of 1999) – that describe in detail the criteria to be followed in the drawing of the state's Congressional, Senate, and House districts. The statutes describe five criteria to be followed in producing each districting plan: 1) Contiguity; 2) Equal population thresholds; 3) Minimizing county breaks; 4) Minimizing municipal breaks; and (as to some districts) 5) Geographic compactness. These five criteria are also traditional districting principles in the drawing of Congressional and state legislative districting plans.

Furthermore, both statutes state that the list of districting guidelines detailed in each statute is exhaustive. MCL § 4.261 mandates that House and Senate plans "shall be enacted using only the following guidelines," while MCL § 3.63 similarly requires that the drawing of congressional plans must follow "only these guidelines in the following order of priority." Hence, it is clear that both statutes not only specify the five districting criteria and their order of priority, but they also prohibit any other considerations, such as the partisan composition of districts or the protection of incumbents.

Appendix A of this report describes the details of the computer-simulated districting algorithm and how these five redistricting criteria are implemented by the computer algorithm in producing Congressional, Senate, and House plans.

Preserving Majority-Minority Districts in Computer-Simulated Plans

When I programmed the computer simulation algorithm, plaintiffs' counsel instructed me to ensure that all simulated maps contained certain majority-minority districts covering Detroit, Southfield, and Flint.

In producing simulated congressional plans, the algorithm freezes the enacted plan's boundaries for congressional Districts 13 and 14, which cover all of Detroit and some surrounding municipalities. In describing the 1,000 computer-simulated congressional plans throughout the remainder of this report, I always include the enacted plan's Districts 13 and 14, even though the boundaries of these two districts are obviously identical in every simulated plan.

In producing simulated Senate plans, the algorithm freezes the enacted plan's boundaries for Senate Districts 1 through 7, which collectively cover all of Wayne County. Wayne County is apportioned seven Senate districts, and in the enacted plan, Senate Districts 1 through 5 are the majority African-American districts covering Detroit. However, once Districts 1 through 5 are frozen into place, the remaining western half of Wayne County must be divided into exactly two Senate districts in order to avoid an unnecessary county break. The only way to draw these two remaining districts while following the MCL § 4.261 redistricting guidelines requires using the same boundaries as the enacted plan's Senate Districts 6 and 7. Therefore I simply instructed the computer to freeze the enacted plan's Senate Districts 1 through 7 in every simulated plan. In describing the 1,000 computer-simulated Senate plans throughout the remainder of this report, I always include the enacted plan's Senate Districts 1 through 7, even though the boundaries of these seven districts are obviously identical in every simulated plan.

In producing simulated House plans, the algorithm freezes the enacted plan's boundaries for House Districts 1 through 10, which collectively cover all of Detroit City, House District 15 (Dearborn), and House District 35 (Southfield). Additionally, the algorithm only permits plans that place the City of Flint into a district with a 55% or higher Black Voting Age Population ("BVAP"). As before, I freeze all majority-African-American districts covering Detroit, which include House Districts 1 through 10. House District 9, however, also includes a small northern fragment of the City of Dearborn. In order to avoid any further breaks of Dearborn, House District 15, consisting of the remainder of Dearborn, must also be frozen exactly as it appears in the enacted plan. Next, as noted earlier, a Southfield-area district with House District 35's racial composition can only be achieved by freezing the precise boundaries of House District 35.

Finally, as noted earlier, the simulation algorithm frequently produced a House district covering the City of Flint that approximates or exceeds the 58% BVAP of House District 34. Therefore, I programmed the algorithm to simply discard any plan failing to create a Flint-area district of at least 55% BVAP.

Thus, in describing the 1,000 computer-simulated congressional plans throughout the remainder of this report, I always include the enacted plan's House Districts 1 through 10, 15, and 35, even though the boundaries of these 12 districts are obviously identical in every simulated plan.

Measuring the Partisanship of Districting Plans

Map drawers and scholars of redistricting most commonly use past election results to assess and compare the partisan composition of any given district, whether in an enacted congressional, Senate, or House plan or in a hypothetical plan. Overlaying these past election results onto a districting plan enables one to estimate the partisanship of each district within each plan. These past election results allow me to then directly compare the partisanship composition of the enacted plan to the partisan composition of the computer-simulated plans. In this section, I explain the set of past elections I use to analyze each district in the enacted plans and the computer-simulated plans, and then I explain the various methods I use in this report to measure the overall partisanship of each districting plan.

Election Results (2006-2016) Used to Measure Districts' Partisanship: I use actual election results from recent, statewide election races in Michigan to assess and compare the partisan performance of each district within the computer-simulated and the enacted congressional, Senate, and House districting plans analyzed in this report. Past voting history in federal and statewide elections is a strong predictor of future voting behavior. Mapmakers thus can and do use past voting history to identify the class of voters, at a precinct-by-precinct level, who are likely to vote for Democratic (or Republican) candidates for Congress. Indeed, that is the entire reason why mapmakers are able to intentionally draw maps so effectively to produce biased political outcomes.

In general, the most reliable method of comparing the partisanship of different legislative districts within a state is to consider whether the districts—and more specifically, the census blocks that comprise each district—have tended to favor Republican or Democratic candidates in

recent, competitive statewide elections, such as the Presidential, Gubernatorial, and US Senate elections. Recent statewide elections provide the most reliable bases for comparisons of different precincts' partisan tendencies because in any statewide election, the anomalous candidate-specific effects that shape the election outcome are equally present in all districts across the state. Statewide elections are thus a better basis for comparison than the results of legislative elections (such as U.S. House and state legislative elections) because the particular outcome of any legislative election may deviate from the long-term partisan voting trends of a constituency, due to factors idiosyncratic to the legislative district as currently constructed. Such factors can include the presence or absence of a quality challenger, anomalous difference between the candidates in campaign efforts or campaign finances, incumbency advantage, candidate scandals, and coattail effects.[2] Because these idiosyncratic factors would change if the legislative district were drawn differently, it is particularly unsuitable to use election results from legislative district when comparing the partisanship of an existing district to a simulated district that would have different boundaries.

Indeed, based on my experience studying redistricting practices in multiple states, it is common for legislative map-drawers to assess the partisanship of a districting plan using the election results of past statewide races, rather than legislative district races. In recent years, for example, legislative map-drawers used and analyzed such statewide election data when producing districting plans in North Carolina, Pennsylvania, and Wisconsin. Map-drawers recognize that legislative district election results are highly sensitive to the district-specific factors listed above, while the results of statewide races are directly comparable across different districts within the state.

To measure the partisanship of each district within Michigan's enacted congressional, Senate, and House plans and each computer-simulated plan, I first obtained from plaintiffs' counsel electronic files reporting block-level election results for all of Michigan's 40 statewide elections held during 2006-2016. I then overlaid these block-level election vote counts onto the district boundaries in each plan, thereby allowing me to calculate the vote totals across these statewide elections within every district in each enacted plan, as well as in each of my computer-

[2] E.g., Alan Abramowitz, Brad Alexander, and Matthew Gunning. "Incumbency, Redistricting, and the Decline of Competition in U.S. House Elections." *The Journal of Politics.* Vol. 68, No. 1 (February 2006): 75-88.

simulated plans. These calculations allow me to determine whether each district in each simulated plan (and each enacted plan) favors Republican or Democratic candidates.

In analyzing the partisanship of each district in Michigan's enacted plans, as well as all of the computer-simulated plans in this report, I aggregated together the results of Michigan's statewide elections held during 2006-2010 and during 2012-2016. These statewide elections include the US Presidential (2008, 2012, 2016), US Senator (2006, 2008, 2012, 2014), Gubernatorial (2006, 2010, 2014), Secretary of State (2006, 2010, 2014), and Attorney General (2006, 2010, 2014) elections. Also included among these statewide contests are the elections for the State Board of Education, the University of Michigan Board of Regents, the Michigan State University Board of Trustees, and the Wayne State University Board of Governors, all of which are held every two years (2006, 2008, 2010, 2012, 2014, 2016). All 40 of these statewide elections were contested by both parties, and most were reasonably close; thus, the combined partisan vote totals from these statewide elections provides an accurate reflection of voters' underlying partisan tendencies across different districts throughout Michigan.

When evaluating the partisanship of Michigan legislative districting plans, I analyze these 40 statewide election contests over two separate time periods: First, I sum the total Republican votes and total Democratic votes cast over all statewide elections during 2006-2010 (a total of 21 election contests), and I determine whether each legislative district had more total Republican or Democratic votes cast during all of these 21 election contests. Second, I sum the total Republican votes and total Democratic votes cast over all statewide elections during 2012-2016 (a total of 19 election contests), and I determine the proportion of votes across these elections in each district that favored each party.

I analyze the 2006-2010 election results and the 2012-2016 election results separately. First, the 2006-2010 election results were the partisan data available to the Michigan Legislature when it produced the state's current enacted districting plans in 2011; Therefore, the 2006-2010 election data potentially provide insight into the Legislature's intent regarding the partisan composition of the districts in the enacted plans. Second, I separately analyzed the results of the 19 statewide elections held during 2012-2016 because these contests are Michigan's most recent races, thus providing an accurate, updated measure of the current partisan composition of different districts throughout Michigan. These 2012-2016 statewide elections also allow us to observe the actual partisan composition of Michigan legislative districts during the elections that

have occurred under the state's 2011 enacted plans. All 19 of these statewide elections were contested by both parties. Thus, the combined partisan vote totals from these statewide elections provides an accurate reflection of voters' underlying partisan tendencies across different districts throughout Michigan.

As an example, Table 1 illustrates how I assess the partisan composition of Congressional Districts 1 and 2 from Michigan's current enacted congressional plan using the results of the 19 statewide elections during 2012-2016. As illustrated in the first two columns, voters in Congressional District 1 cast a total of 210,845 votes for the Republican Donald Trump and 133,251 votes for Democrat Hillary Clinton. When summed across all 19 of the statewide elections during 2012-2016, District 1 voters cast a combined total of 4,408,972 votes in favor of the various Republican candidates in these races and 3,434,286 votes in favor of the Democratic candidates; in other words, 56.21% of the two-party votes cast during these elections were in favor of a Republican candidate. The final two columns in this Table perform the same calculations for Congressional District 2, showing that 60.77% of votes cast in the district were in favor of a Republican candidate. Together, these calculations allow us to conclude that both districts generally favor Republican candidates, but Congressional District 2 is slightly more Republican-leaning than Congressional District 1.

Finally, as two additional measures of partisanship, I calculate each district's partisanship by measuring Republican candidates' share of the two-party votes in the 2006-2010 education and university board elections, and I also calculate Republicans' share of the two-party votes in the 2012-2016 education and university board elections. These elections include all races for the State Board of Education, the University of Michigan Board of Regents, the Michigan State University Board of Trustees, and the Wayne State University Board of Governors. These education and university board election results lead to substantially the same partisan estimates as using all statewide elections during these time periods. Nevertheless, I present these two additional measures because it has been common practice in Michigan to measure the partisanship of legislative districts using the aggregated outcomes of recent education and university board elections.

Table 1:
Calculating the Partisan Composition of Districts Using Past Statewide Election Results

	Congressional District 1 (2011 Enacted Plan)		Congressional District 2 (2011 Enacted Plan)	
Election Contest	**Republican Votes:**	**Democratic Votes:**	**Republican Votes:**	**Democratic Votes:**
2016 US President	210,845	133,251	193,209	132,454
2016 Board of Education	334,645	204,472	355,630	203,302
2016 Univ of Michigan Regents	330,565	214,574	353,649	208,767
2016 Michigan State Trustees	325,786	218,958	348,269	212,403
2016 Wayne State Governors	314,602	209,715	340,127	205,248
2014 Governor	136,045	109,144	135,681	75,452
2014 Secretary of State	141,340	93,644	136,784	67,324
2014 Attorney General	144,581	91,375	134,022	68,253
2014 US Senator	123,453	116,481	116,302	88,910
2014 Board of Education	221,422	180,911	227,377	136,682
2014 Univ of Michigan Regents	218,700	177,295	228,424	133,213
2014 Michigan State Trustees	219,534	170,800	226,461	130,383
2014 Wayne State Governors	206,791	175,778	217,096	132,830
2012 US President	189,420	160,210	184,762	142,079
2012 US Senator	154,868	182,554	170,798	146,329
2012 Board of Education	292,357	247,273	319,459	222,504
2012 Univ of Michigan Regents	283,190	250,296	310,567	228,690
2012 Michigan State Trustees	289,739	244,387	317,064	218,466
2012 Wayne State Governors	271,089	253,168	300,809	226,611
Total Votes in all 2012-2016 Statewide Elections:	**4,408,972 (56.21%)**	**3,434,286 (43.79%)**	**4,616,490 (60.77%)**	**2,979,900 (39.23%)**

After measuring each district's partisanship by aggregating together all statewide elections during 2006-2010 and 2012-2016, as well as just the subset of education and university board elections, I then proceed to measure the overall partisanship of each entire districting plan using the following three different measurements:

The Number of Republican and Democratic Districts: The most basic and commonly-used method of measuring the partisanship of an entire districting plan is to simply count up the number of Republican and Democratic-favoring districts within the plan. This basic quantity allows me to directly compare the partisan distribution of an enacted plan to the partisanship of computer-simulated districting plans. Using this measure, I am also able to precisely quantify the difference in partisanship between the enacted plan and any simulated plan.

To illustrate an example, Michigan's enacted congressional plan contains a total of nine districts (Districts 1, 2, 3, 4, 6, 7, 8, 10, 11) in which Republican candidates received more total votes than Democratic candidates over the course of the 19 statewide elections during 2012-2016. In the remaining five Congressional Districts in the enacted plan (Districts 5, 9, 12, 13, and 14), Democratic candidates received more combined votes than Republican candidates over the course of these 19 statewide elections.

I find that overall, using recent past statewide elections has been an extremely accurate predictor of actual legislative election outcomes in the enacted plans' districts. For example, in 9 of the 14 districts in the enacted congressional plan, the total number of Republican votes cast outnumbered the total Democratic votes cast during the 2006-2010 statewide elections. These same 9 districts also had more Republican than Democratic votes cast during the 2012-2016 statewide elections. These 9 enacted districts have all elected Republican congressional representatives during each congressional election held under the enacted plan (2012, 2014, and 2016). The remaining 5 districts in the enacted congressional plan had more Democratic than Republican votes cast during the 2006-2010 statewide elections, as well as during the 2012-2016 statewide elections. These 5 enacted congressional districts have all elected Democratic congressional representatives during each congressional election held under the enacted plan (2012, 2014, and 2016). Hence, the use of 2006-2010 and 2012-2016 statewide elections has been a perfectly accurate predictor of actual congressional election outcomes in every election held under the enacted plan.

The 2006-2010 and 2012-2016 statewide elections have been similarly accurate in predicting state legislative election outcomes. In the enacted House plan, 61 out of the 110 House districts contained more Republican than Democratic votes cast during the 2006-2010 statewide elections, as well as during the 2012-2016 statewide elections. These 61 Republican-leaning districts correspond closely to the actual partisan outcomes of the 2012, 2014, and 2016 State House elections, which have produced 59, 63, and 63 Republican victories, respectively, or an average of 61.7 Republican victories. Finally, in the enacted Senate plan, 23 of the 38 Senate districts contained more Republican than Democratic votes cast during the 2006-2010 statewide elections, and 24 of the 38 districts had more Republican than Democratic votes cast during the 2012-2016 statewide elections. Only one set of Senate elections has been held under the enacted Senate plan: Republicans won 27 seats in the November 2014 general election.

By comparing the number of Republican districts in an enacted plan to the number in each of the computer-simulated plans, I am able to evaluate whether or not the particular number of Republican-favoring districts in an enacted plan was a partisan outlier.

The Median-Mean Difference: The Median-Mean Difference is another accepted method that redistricting scholars commonly use for comparing the relative partisan bias of different districting plans.[3] For any districting plan, the mean is simply calculated as average of the Republican vote shares across all districts, and the median is the Republican vote share in the district where Republicans performed the middle-best; if there are an even number of districts across the entire plan, then the median is calculated as the average Republican vote share in the two districts where the Republicans performed the middle-best. For example, in any congressional districting plan in Michigan, the median would be the average vote share in the Republicans' seventh and eighth-best congressional districts. In any State Senate plan, the median would be the average vote share in the Republicans' nineteenth and twentieth-best Senate districts. The Median-Mean Difference is then calculated as the median district vote share, minus the mean district vote share. Thus higher, positive values indicate that the median district's Republican vote share is higher than the mean district-level Republican vote share.

For example, using the aggregated results of Michigan's 2006-2010 statewide elections, the 14 districts in Michigan's enacted congressional plan have a mean Republican vote share of 46.80%, while the median district has a Republican vote share of 53.52%. Thus, the enacted congressional plan has a Median-Mean Difference of 6.72%, indicating that the median district is skewed significantly more Republican than the plan's average district. In other words, the enacted plan distributes voters across districts in such a way that most districts are significantly more Republican-leaning than the average congressional district, while Democratic voters are more heavily concentrated in a minority of the congressional districts. This skew in the enacted plan thus creates a significant advantage for Republicans by giving them stronger control over the median district.

An important question, however, is whether this significant Median-Mean Difference arises naturally from applying the statutory redistricting guidelines to Michigan's census

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[3] Robin E. Best and Michael D. McDonald, "Unfair Partisan Gerrymanders in Politics and Law: A Diagnostic Applied to Six Cases." 14 Election Law Journal Vol. 14, No. 4 (2015). Samuel Wang, "Three Practical Tests for Gerrymandering: Application to Maryland and Wisconsin." 15 Election Law Journal Vol. 15, No. 4 (2016).

boundaries, given the state's unique voter geography. Or rather, is the skew in the enacted plan's Median-Mean Difference explainable only as the product of an intentional partisan effort to favor one party over another in the drawing of the districts? By comparing the Median-Mean Difference of an enacted plan to that of the computer-simulated plans, I am able to evaluate whether or not such an extreme Republican-favoring skew in the Median-Mean Difference was a necessary result of a districting process.

The Efficiency Gap: A third commonly-used measure of a districting plan's partisan bias is the efficiency gap.[4] To calculate the efficiency gap of any enacted or computer-simulated plan, I first determine the partisan leaning of each simulated district and each individual district, as measured by any given set of election results, such as the 2012-2016 statewide elections. Using the 2012-2016 statewide elections as a simple measure of district partisanship, I then calculate each districting plan's efficiency gap using the method outlined in *Partisan Gerrymandering and the Efficiency Gap*[5]. Districts are classified as Democratic victories if, across these statewide elections, the sum total of Democratic votes in the district during these elections exceeds the sum total of Republican votes; otherwise, the district is classified as Republican. For each party, I then calculate the total sum of surplus votes in districts the party won and lost votes in districts where the party lost. Specifically, in a district lost by a given party, all of the party's votes are considered lost votes; in a district won by a party, only the party's votes exceeding the 50% threshold necessary for victory are considered surplus votes. A party's total wasted votes for an entire districting plan is the sum of its surplus votes in districts won by the party and its lost votes in districts lost by the party. The efficiency gap is then calculated as total wasted Republican votes minus total wasted Democratic votes, divided by the total number of two-party votes cast statewide across all seven elections.

Thus, the theoretical importance of the efficiency gap is that it tells us the degree to which more Democratic or Republican votes are wasted across an entire districting plan. A significantly positive efficiency gap indicates far more Republican wasted votes, while a significantly negative efficiency gap indicates far more Democratic wasted votes.

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[4] Eric McGhee, "Measuring Partisan Bias in Single-Member District Electoral Systems." Legislative Studies Quarterly Vol. 39, No. 1: 55–85 (2014).

[5] Nicholas O. Stephanopoulos & Eric M. McGhee, *Partisan Gerrymandering and the Efficiency Gap,* 82 University of Chicago Law Review 831 (2015).

In addition to calculating the efficiency gap using each district's votes from the 2012-2016 statewide elections, as described above, I also separately calculate the efficiency gap using the combined results from the 2006-2010 statewide elections. As before, I sum up the total Democratic votes and total Republican votes from across these statewide elections and calculate a single efficiency gap for each simulated and enacted districting plan using these combined partisan vote counts.

An important question, however, is whether an enacted plan's Efficiency Gap arises naturally from applying the statutory redistricting guidelines to Michigan's census boundaries, given the state's unique voter geography. Or rather, is the skew in the enacted plan's Efficiency Gap explainable only as the product of an intentional partisan effort to favor one party over another in the drawing of the districts? By comparing the Efficiency Gap of an enacted plan to that of the computer-simulated plans, I am able to evaluate whether or not such an extreme Republican-favoring skew in the Efficiency Gap was a necessary result of a districting process.

Comparison of Simulated Congressional Plans to the Enacted Congressional Plan

To evaluate the enacted Congressional Plan, I produced and analyzed a set of 1,000 simulated congressional plans using the computer simulation algorithm. As described earlier, the algorithm strictly follows the five non-partisan redistricting guidelines detailed in MCL § 3.63: Contiguity, perfect equalization of district populations, minimizing county breaks, minimizing municipal breaks, and geographic compactness. Table 2 compares how the enacted congressional plan and the 1,000 computer-simulated plans perform with respect to these various districting criteria.

Figure 1 compares the partisanship of the simulated plans to the partisanship of the enacted congressional plan. Specifically, Figure 1 uses all statewide elections during 2006-2010 (upper histogram) and during 2012-2016 (lower histogram) to measure the number of Republican-leaning districts created by the 1,000 simulated plans. As measured by these election results, the simulated plans all create from 6 to 8 Republican districts out of 14 total districts. Using the 2006-2010 statewide elections as a baseline, most of the simulated plans contain 7 Republican districts; using the 2012-2016 statewide elections as a baseline, the vast majority of simulated plans contain 7 Republican districts.

By contrast, the enacted congressional plans contains 9 Republican districts, using either set of statewide elections. In each histogram, the red dashed line indicates the number of Republican districts created by the enacted congressional plan. The finding that none of the 1,000 computer-simulated plans ever reaches the enacted plan's creation of 9 Republican districts demonstrates, with over 99.9% certainty, that the enacted plan created a pro-Republican partisan outcome that is a partisan outlier.

Figure 2 confirms this pro-Republican partisan bias in the enacted plan by analyzing districts using the education and university board elections held during 2006-2010 (upper histogram) and during 2012-2016 (lower histogram) to measure the number of Republican-leaning districts in each plan. As measured by these election results, the simulated plans all create from 5 to 8 Republican districts out of 14 total districts. Using the 2006-2010 statewide elections, most of the simulated plans contain 6 Republican districts; using the 2012-2016 statewide elections, the vast majority of simulated plans contain 7 Republican districts. By contrast, the enacted congressional plans contains 9 Republican districts, using either set of statewide elections. This is an outcome never observed in any of the 1,000 computer simulated plans, thus confirming that the enacted plan is a partisan outlier.

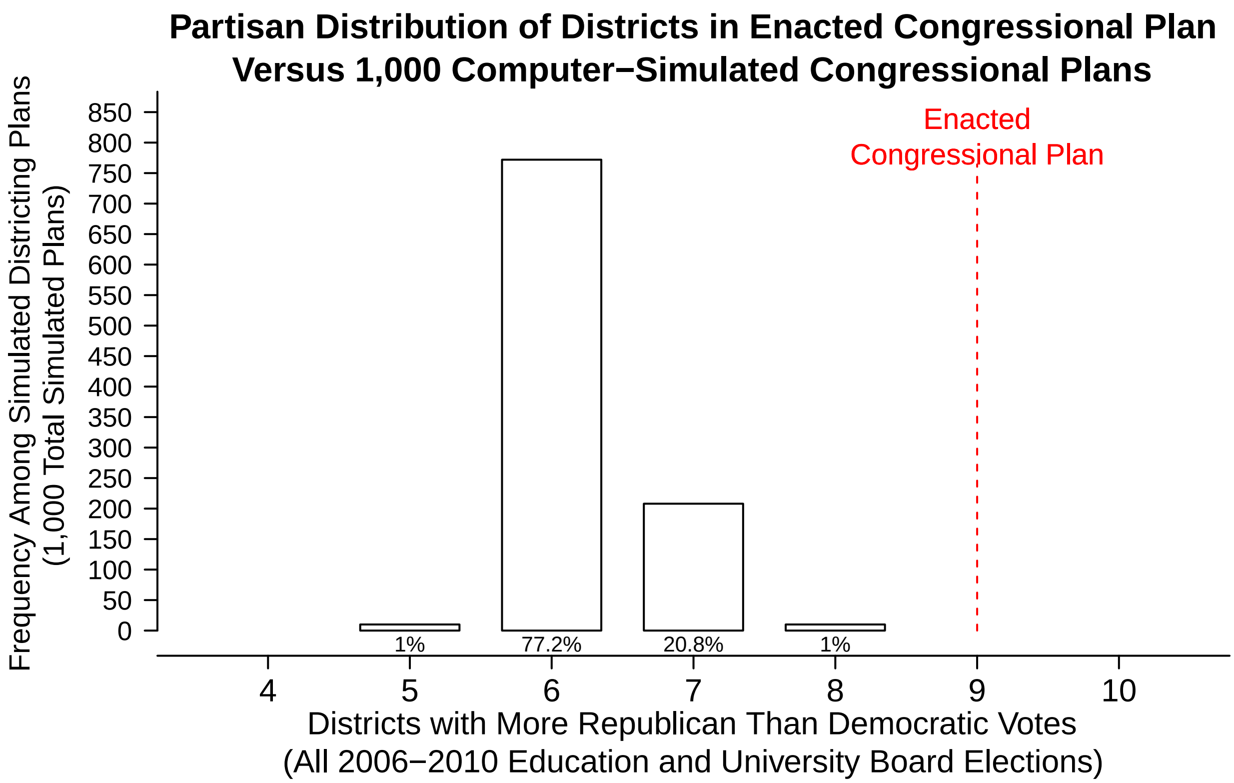
Why did the enacted congressional plan fail to produce geographically compact districts? As Figures 1 – 4 collectively illustrate, the enacted congressional plan is entirely outside the range of all 1,000 simulated maps with respect to both geographic compactness and the partisan distribution of seats

Collectively, these findings suggest that the enacted congressional plan was drawn under a process in which a partisan goal – the creation of 9 Republican districts – predominated. I am thus able to conclude, with over 99.9% statistical certainty, that the enacted congressional plan created districts less compact than what would have reasonably emerged from a districting process not driven by partisan intent.

Table 2:
Comparison of the Enacted Congressional Plan (Act 128 of 2011) to Computer-Simulated Congressional Plans

	Enacted Congressional Plan (Public Act 128 of 2011)	**1,000 Computer-Simulated Congressional Maps:**
Number of County Breaks, as defined by MCL 3.54(b) (Including Wayne County):	11	10 (1,000 simulated maps)
Number of Counties Divided into Multiple Districts (Including Wayne County):	11	9 (22 simulated maps) 10 (978 simulated maps)
Number of Municipal Breaks, as defined by MCL 3.63(c) (Excluding Detroit):	12	9 (18 simulated maps) 10 (982 simulated maps)
Number of Municipalities Divided into Multiple Districts (Excluding Detroit):	12	9 (18 simulated maps) 10 (982 simulated maps)
Compactness as Defined by MCL 3.63(c)(vii) Total Land Area Within Districts' Circumscribing Circles but Outside of their Respective Districts (Lower Area Indicates Greater Compactness):	120,210 Sq. Km.	95,171 to 114,898 Sq. Km.
Compactness as Defined by MCL 3.63(c)(vii) Average Ratio of Each District's Land Area to the Land Area Inside the District's Circumscribing Circle (Higher Ratio Indicates Greater Compactness):	0.463	0.471 to 0.509
Compactness, Measured Using Average Reock Score (Higher Score Indicates Greater Compactness):	0.389	0.433 to 0.474
Districts with More Republican than Democratic Votes (All 2006-2010 statewide elections):	9	6 (227 simulated maps) 7 (453 simulated maps) 8 (320 simulated maps)
Districts with More Republican than Democratic Votes (All 2012-2016 statewide elections):	9	6 (5 simulated maps) 7 (875 simulated maps) 8 (120 simulated maps)
Districts with More Republican than Democratic Votes (All 2006-2010 Education and University Board elections):	9	5 (10 simulated maps) 6 (772 simulated maps) 7 (208 simulated maps) 8 (10 simulated maps)
Districts with More Republican than Democratic Votes (All 2012-2016 Education and University Board elections):	9	6 (4 simulated maps) 7 (865 simulated maps) 8 (131 simulated maps)

Figure 1:


Partisan Distribution of Districts in Enacted Congressional Plan
Versus 1,000 Computer−Simulated Congressional Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Enacted
Congressional Plan
1%
77.2%
20.8%
1%
4
5
6
7
8
9
10
Districts with More Republican Than Democratic Votes
(All 2006−2010 Education and University Board Elections)

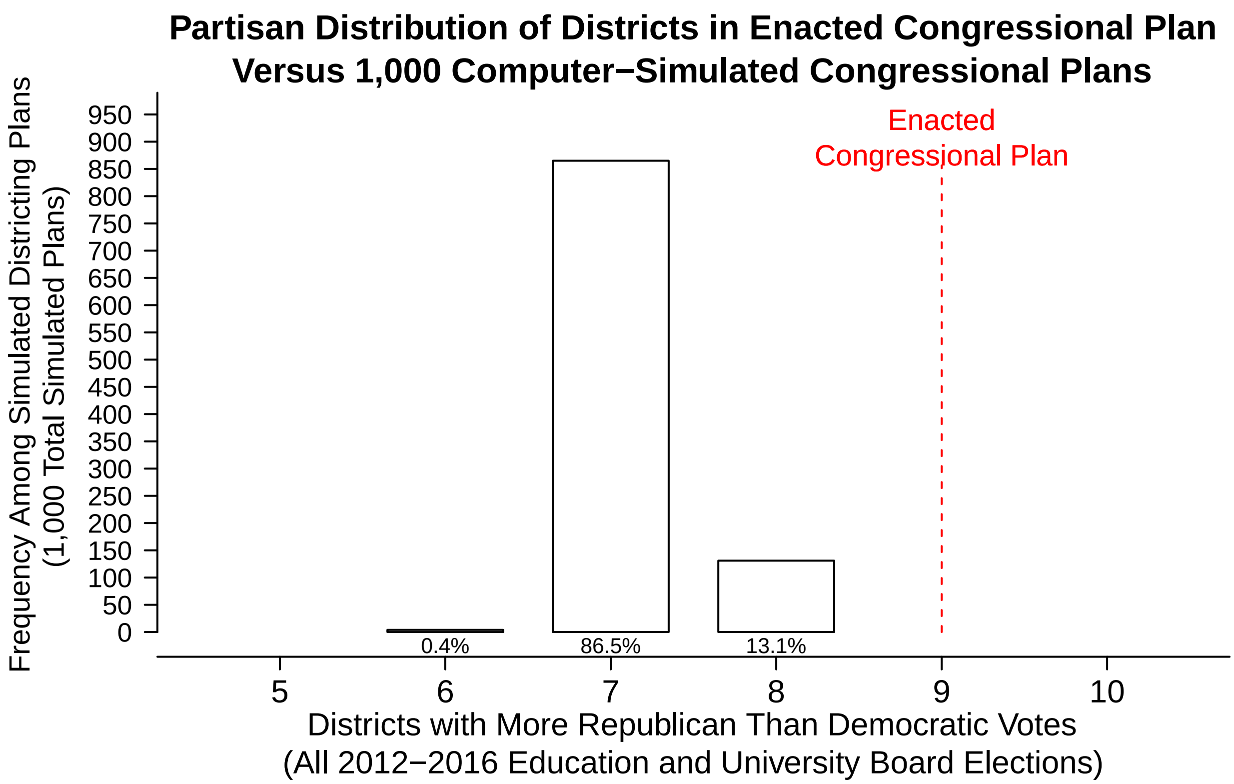
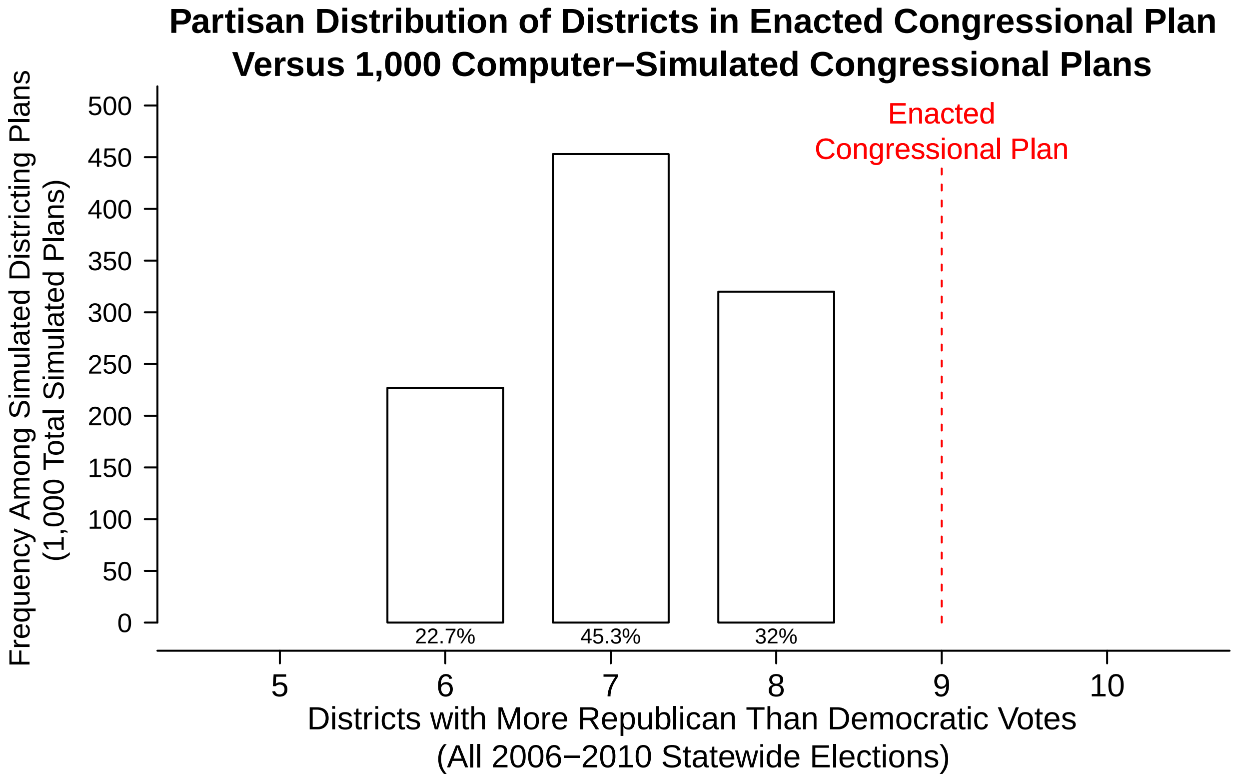
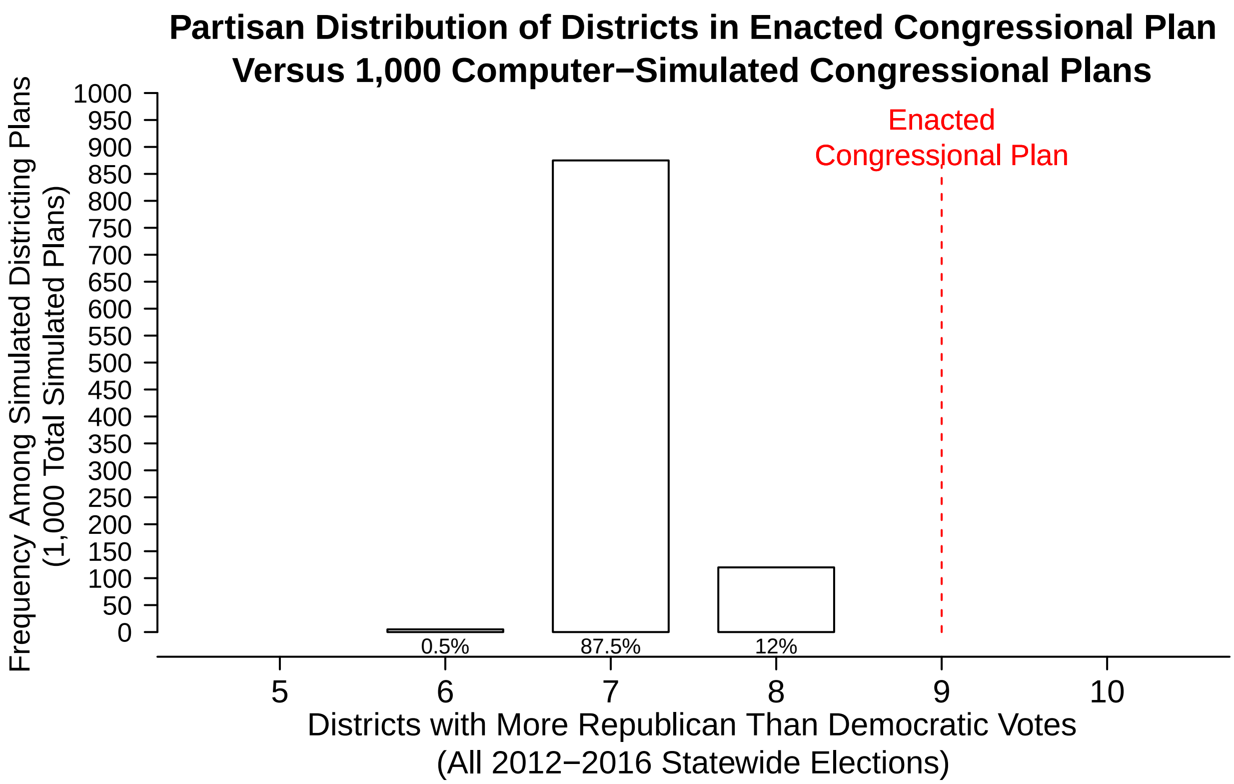

Partisan Distribution of Districts in Enacted Congressional Plan
Versus 1,000 Computer−Simulated Congressional Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Enacted
Congressional Plan
0.4%
86.5%
13.1%
5
6
7
8
9
10
Districts with More Republican Than Democratic Votes
(All 2012−2016 Education and University Board Elections)

Figure 2:


Partisan Distribution of Districts in Enacted Congressional Plan
Versus 1,000 Computer−Simulated Congressional Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
500
450
400
350
300
250
200
150
100
50
0
Enacted
Congressional Plan
22.7%
45.3%
32%
5
6
7
8
9
10
Districts with More Republican Than Democratic Votes
(All 2006−2010 Statewide Elections)


Partisan Distribution of Districts in Enacted Congressional Plan
Versus 1,000 Computer−Simulated Congressional Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
1000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
250
200
150
100
50
0
Enacted
Congressional Plan
0.5%
87.5%
12%
5
6
7
8
9
10
Districts with More Republican Than Democratic Votes
(All 2012−2016 Statewide Elections)

Robustness Checks Using Alternative Measures of Partisan Bias: Comparing the number of Republican-favoring districts, as measured by recent past statewide elections, is the most comprehensive and statistically valid method of measuring the partisan bias of the enacted congressional plan, as compared to the computer-simulated plans. Counting the number of Republican and Democratic-favoring districts in a plan, as measured using recent statewide elections, is a broad, durable and sufficient measurement of districting plan partisanship, particularly since it is common practice in Michigan to assess the partisanship of districts by aggregating together the results of recent statewide education and university board elections.

What follows in the remainder of this section, then, is a completely separate set of analyses in which I examine the simulated plans and the enacted congressional plan using two alternative measures of partisanship and electoral bias: The Median-Mean Difference and the Efficiency Gap. These two alternative measures are presented as robustness checks, and the conclusions reached in the previous sections do not depend on these robustness checks. I introduce these alternative measures of districting-plan partisanship in order to illustrate the findings of my simulation analysis in more relatable ways and to demonstrate the robustness of these findings.

I first measure the Median-Mean Difference of the enacted congressional plan and then compare it to the Mean-Median Differences of the 1,000 computer-simulated congressional plans. As described earlier in this report, using the aggregated results of Michigan's 2006-2010 statewide elections, the 14 districts in Michigan's enacted congressional plan have a Median-Mean Difference of 6.72%. The enacted plan's districts have a mean Republican vote share of 46.80%, while the median district has a Republican vote share of 53.52%. Thus, the enacted congressional plan has a Median-Mean Difference of 6.72%, indicating that the median district is skewed significantly more Republican than the plan's average district. Similarly, using the results of Michigan's 2012-2016 statewide elections, the Median-Mean Difference of the enacted congressional plan is 7.55%, confirming that the median district is skewed significantly more Republican than the enacted plan's average district. In other words, the enacted plan distributes voters across districts in such a way that most districts are significantly more Republican-leaning than the average congressional district, while Democratic voters are more heavily concentrated in a minority of the congressional districts. This skew in the enacted plan thus creates a

significant advantage for Republicans by giving them stronger control over the median district in the enacted congressional plan.

Figure 3:

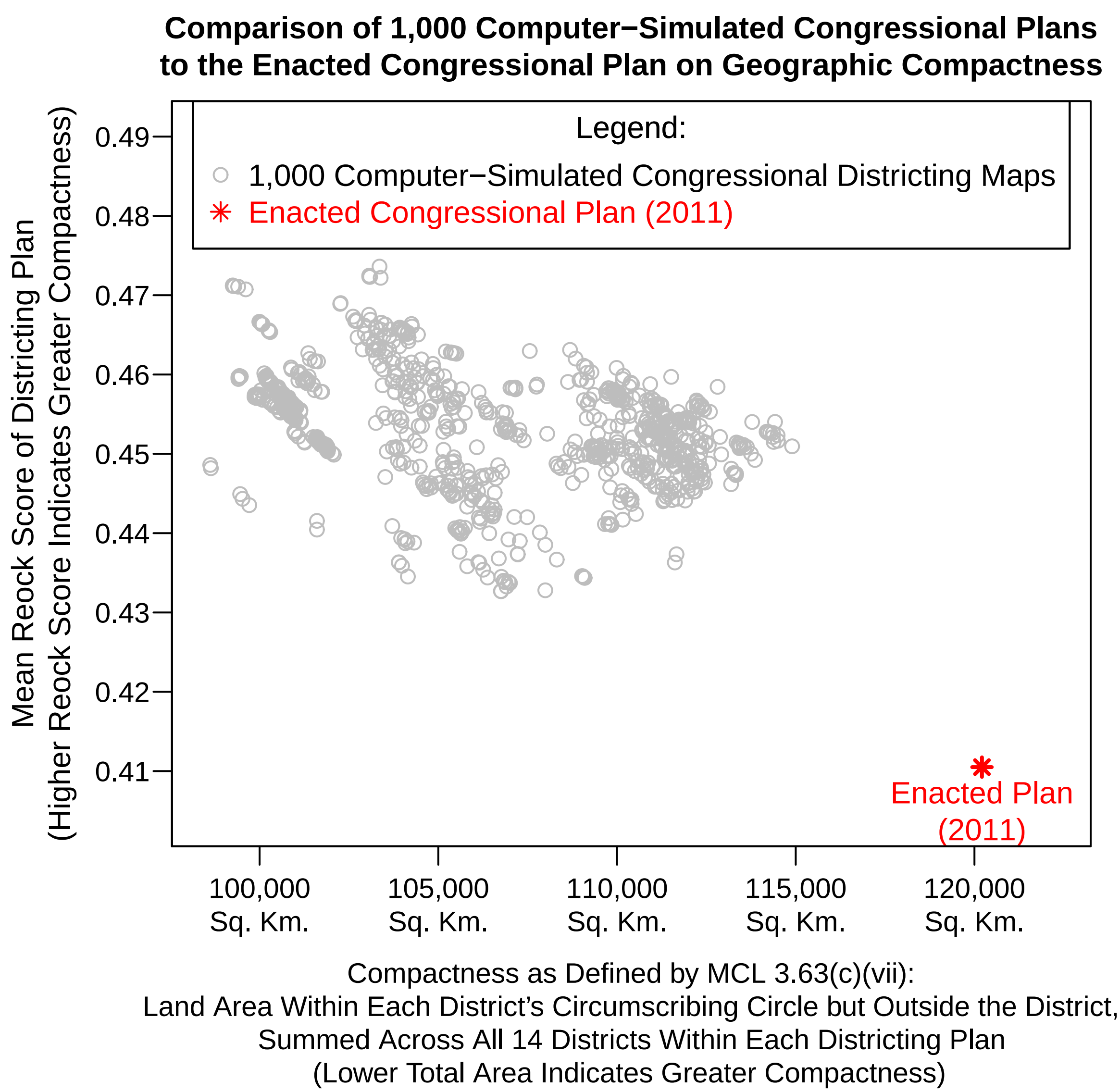
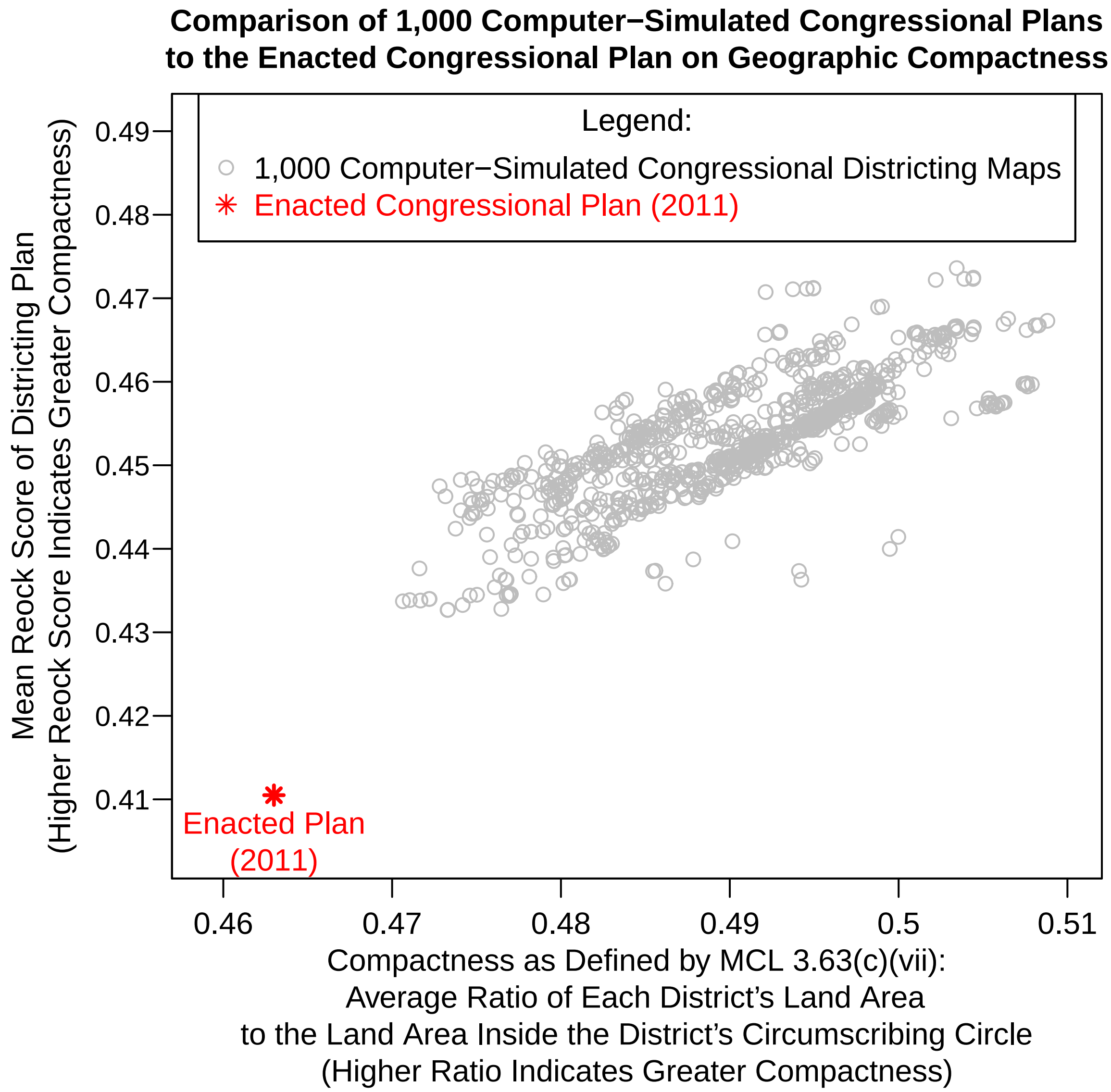


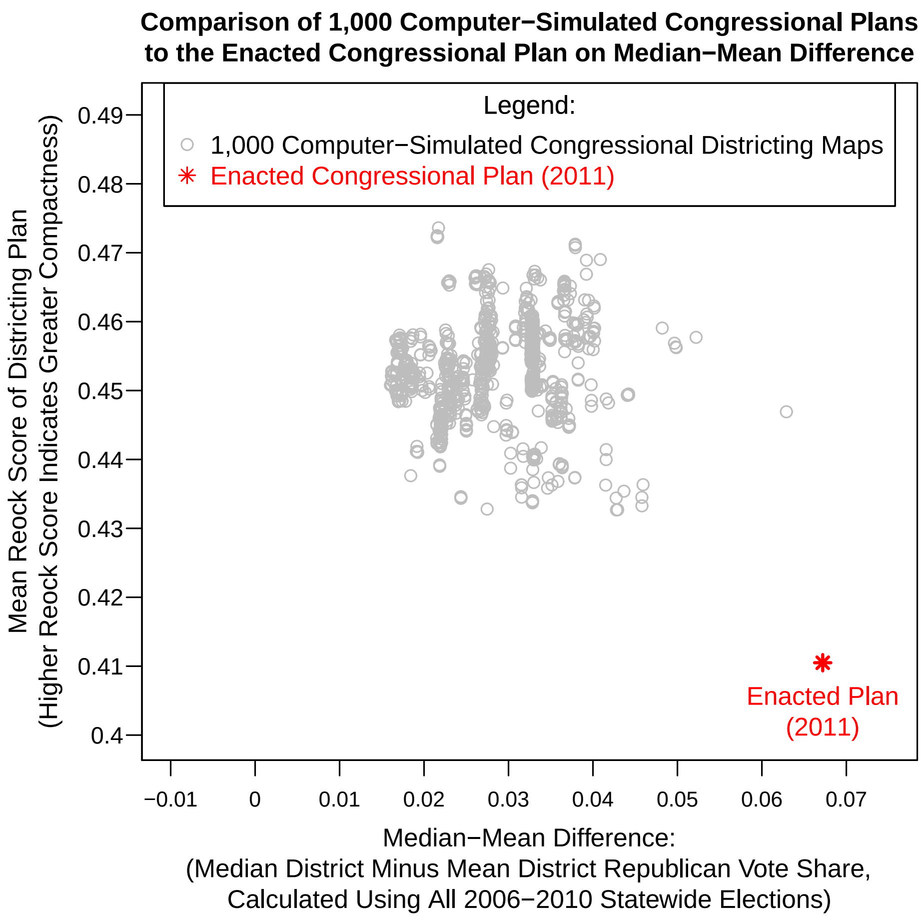
Figure 4:

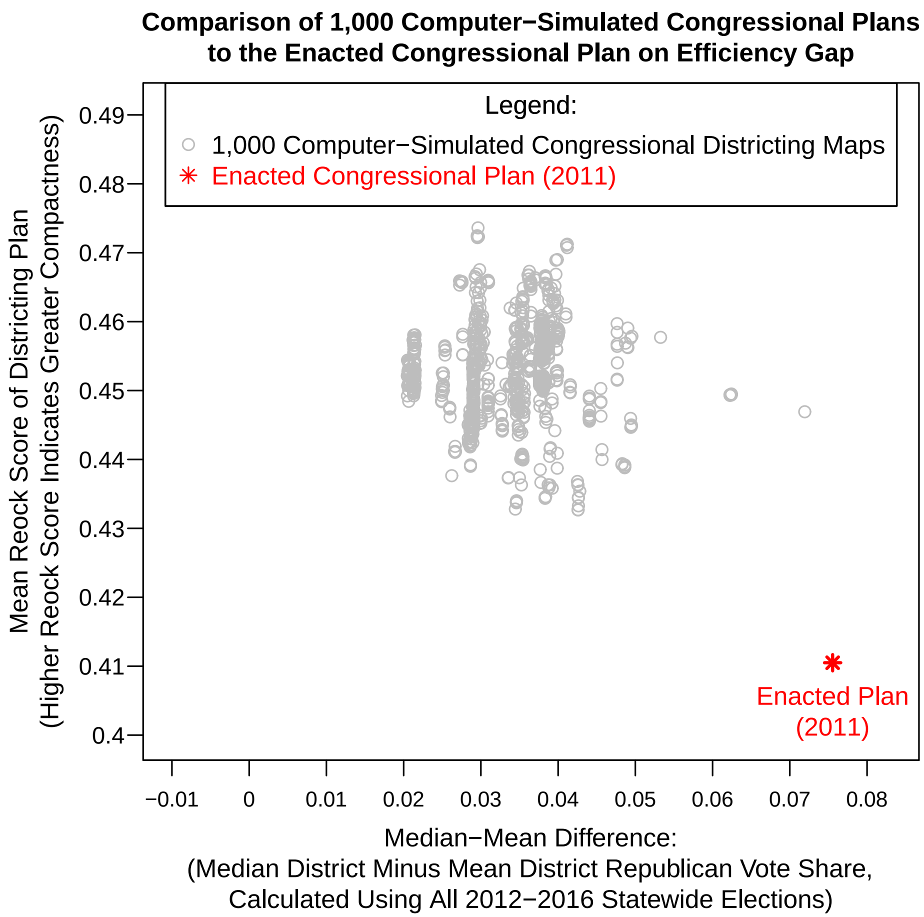

Comparison of 1,000 Computer−Simulated Congressional Plans
to the Enacted Congressional Plan on Geographic Compactness
Legend:
1,000 Computer−Simulated Congressional Districting Maps
Enacted Congressional Plan (2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
Enacted Plan
(2011)
0.46
0.47
0.48
0.49
0.5
0.51
Compactness as Defined by MCL 3.63(c)(vii):
Average Ratio of Each District's Land Area
to the Land Area Inside the District's Circumscribing Circle
(Higher Ratio Indicates Greater Compactness)

How does this Median-Mean Difference of the enacted plan compare to that of the 1,000 computer-simulated plans? Figure 5 presents comparisons of the enacted congressional plan to the 1,000 computer-simulated plans on their Median-Mean Differences. The left side of this Figure calculates the Median-Mean Difference using the aggregated results of Michigan's 2006-2010 statewide elections, while the right side of the Figure uses the aggregated results of the 2012-2016 statewide elections. In both diagrams, the horizontal axis depicts the Median-Mean Difference of each plan, while the vertical axis depicts the Reock score of each plan, measuring the plan's geographic compactness. In each diagram, the red star represents the enacted congressional plan, while the gray circles represent the 1,000 computer-simulated plans.

Using either set of elections, it is very clear that the enacted congressional plan is significantly more skewed in favor of Republicans than every single one of the 1,000 computer-simulated plans. Almost all of the computer-simulated plans have a Median-Mean Difference between 2% to 3.8%, using the 2006-2010 statewide elections, and between 2% to 3.6%, using the 2012-2016 statewide elections. Not a single simulated plan comes even close to the enacted plan's extreme Median-Mean Difference of 6.72%, using the 2006-2010 statewide elections, and 7.55%, using the 2012-2016 statewide elections. I thus conclude, with extremely strong statistical certainty, that the enacted plan's extreme Median-Mean Difference is clearly not the result of Michigan's natural political geography, combined with the application of Michigan's statutory redistricting guidelines. It is the result of partisan intent.

Figure 5:


Comparison of 1,000 Computer−Simulated Congressional Plans
to the Enacted Congressional Plan on Median−Mean Difference
Legend:
1,000 Computer−Simulated Congressional Districting Maps
Enacted Congressional Plan (2011)
Enacted Plan
(2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
−0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
Median−Mean Difference:
(Median District Minus Mean District Republican Vote Share,
Calculated Using All 2006−2010 Statewide Elections)

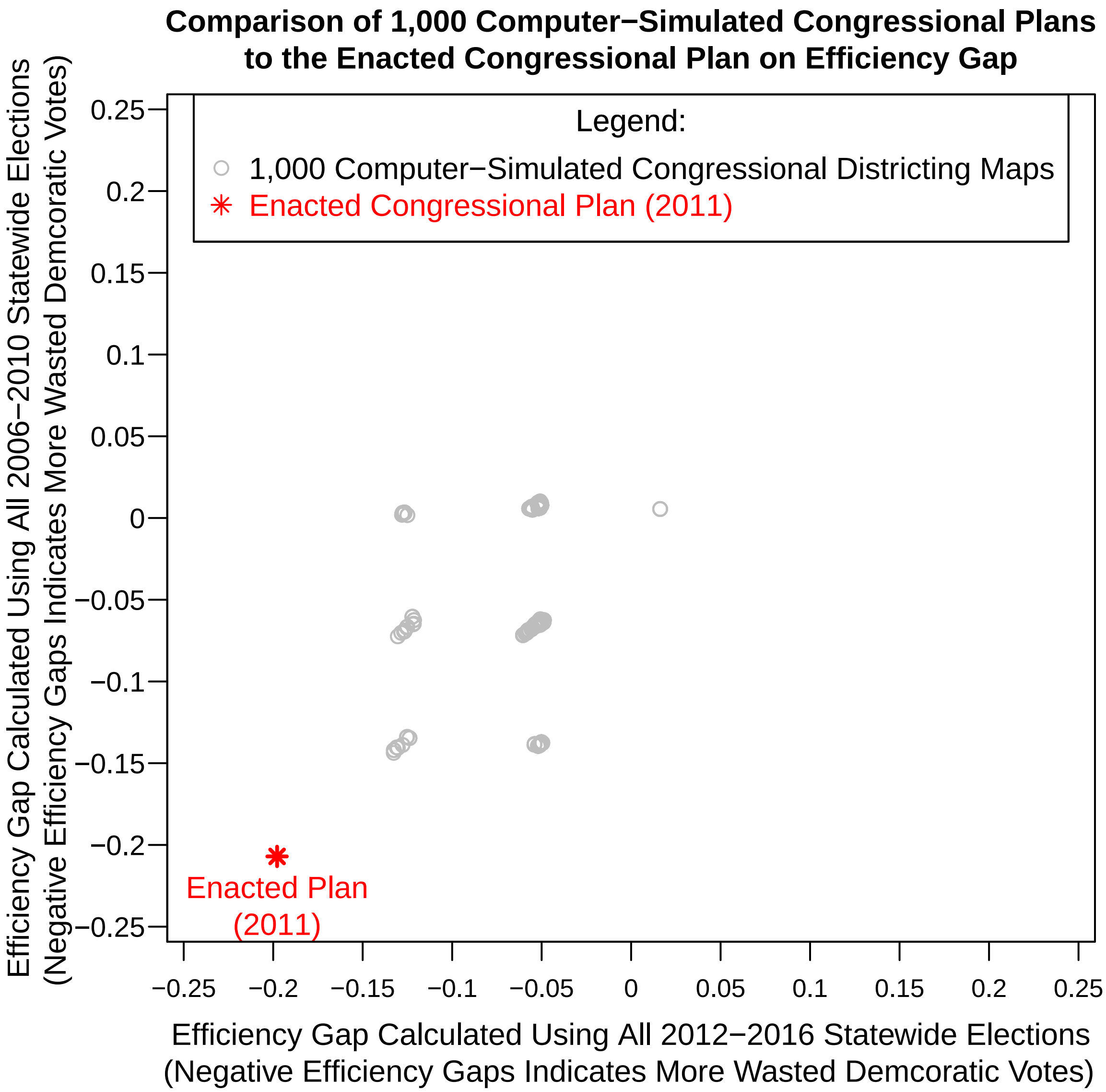

Comparison of 1,000 Computer−Simulated Congressional Plans
to the Enacted Congressional Plan on Efficiency Gap
Legend:
1,000 Computer−Simulated Congressional Districting Maps
Enacted Congressional Plan (2011)
Enacted Plan
(2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
−0.01
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
Median−Mean Difference:
(Median District Minus Mean District Republican Vote Share,
Calculated Using All 2012−2016 Statewide Elections)

The fact that the 1,000 simulated plans in Figure 5 all produce a small but positive Median-Mean Difference results, at least in part, from the fact that, as noted earlier, the simulation algorithm simply freezes Congressional Districts 13 and 14 (covering Detroit City) from the enacted plan, without attempting to draw these two districts' boundaries in a partisan-neutral manner. The small Median-Mean Differences in the computer-simulated plans may also partially reflect a modest skew in Michigan's voter geography that slightly benefits the Republicans in districting. This modest skew in the simulated districting plans may result naturally from Democratic voters' tendency to cluster in urban areas of Michigan, as I have explained in my previous academic research.[6] But more importantly, even when combined with the skew from freezing majority-minority districts, the range of this natural skew, as shown in Figure 5, is always much smaller than the extreme 6.72% Median-Mean Difference observed in the enacted congressional plan. Hence, these results confirm the main finding that the enacted plan creates an extreme partisan outcome that cannot be explained by Michigan's voter geography or by the application of the MCL § 3.63 redistricting guidelines. Instead, the extremity of the enacted plan's Median-Mean Difference can only be explained by a districting process that pursued a partisan goal.

Next, I compare the enacted congressional plan to the 1,000 computer-simulated congressional plans using the efficiency gap. Figure 6 illustrates these efficiency gap calculations: The vertical axis depicts each plan's efficiency gap using the 2006-2010 statewide elections, while the horizontal axis depicts each plan's efficiency gap using the 2012-2016 statewide elections. The 1,000 gray circles in this Figure represent the computer-simulated districting plan, while the red star represents the enacted congressional plan.

[6] Jowei Chen and Jonathan Rodden, 2013. "Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures" *Quarterly Journal of Political Science*, 8(3): 239-269; Jowei Chen and David Cottrell, 2016. "Evaluating Partisan Gains from Congressional Gerrymandering: Using Computer Simulations to Estimate the Effect of Gerrymandering in the U.S. House." *Electoral Studies*, Vol. 44, No. 4: 329-430.

Figure 6:


Comparison of 1,000 Computer−Simulated Congressional Plans to the Enacted Congressional Plan on Efficiency Gap
Legend:
1,000 Computer−Simulated Congressional Districting Maps
Enacted Congressional Plan (2011)
Enacted Plan (2011)
Efficiency Gap Calculated Using All 2006−2010 Statewide Elections (Negative Efficiency Gaps Indicates More Wasted Demcoratic Votes)
Efficiency Gap Calculated Using All 2012−2016 Statewide Elections (Negative Efficiency Gaps Indicates More Wasted Demcoratic Votes)
0.25
0.2
0.15
0.1
0.05
0
−0.05
−0.1
−0.15
−0.2
−0.25

First, this Figure reveals that most of the 1,000 simulated districting plans are reasonably neutral with respect to electoral bias, as measured by the efficiency gap. Using either set of elections, over half of the simulated plans exhibit an efficiency gap within 5% of zero, indicating minimal electoral bias in favor of either party. In fact, 22.5% of the simulations produce an efficiency gap between -1.0% and +1.0%, using the 2006-2010 statewide elections. These simulated plans with nearly zero efficiency gap are all plans that contain exactly six Republican and eight Democratic-favoring districts, as measured by the 2006-2010 statewide election results. These patterns illustrate that a non-partisan districting process very commonly produces a neutral congressional plan in Michigan with minimal electoral bias, as measured by efficiency gap.

Second, it is also important to note that the computer simulations produce plans with both slightly positive and negative efficiency gaps. But the broader, more striking finding in this analysis is that over one-half of the simulated plans produced by the partisan-neutral simulation algorithm strictly following traditional districting criteria are within 5% of a zero efficiency gap. Hence, it is clearly not difficult to create a map that is relatively unbiased according to the efficiency gap measure and follows the MCL § 3.63 redistricting guidelines. To produce a map with significant electoral bias deviating by over 15% from a zero efficiency gap would require extraordinary and deliberate partisan map-drawing efforts.

Third, Michigan's enacted congressional plan, denoted in Figure 6 as a red star, produces an efficiency gap that is extremely inconsistent with and outside of the entire range of the 1,000 computer-simulated plans. The enacted plan creates an efficiency gap of -20.7% using the 2006-2010 statewide elections and -19.8% using the 2012-2016 statewide elections, indicating that the plan consistently results in significantly more wasted Democratic votes than wasted Republican votes. Thus, the level of electoral bias in the enacted congressional plan is not only entirely outside of the range produced by the simulated plans, the enacted plan's efficiency gap is far more biased than even most biased of the 1,000 simulated plans. The improbable nature of the enacted plan's efficiency gap allows us to conclude with overwhelmingly high statistical certainty that the enacted congressional plan is a partisan outlier.

Comparison of Simulated Senate Plans to the Enacted Senate Plan

To evaluate Michigan's enacted Senate Plan, I produced and analyzed a set of 1,000 simulated Senate plans using the computer simulation algorithm. As described earlier, the algorithm strictly follows the five non-partisan redistricting guidelines detailed in MCL § 4.261: Contiguity, equalization of district populations within the thresholds mandated by MCL § 4.261, minimizing county breaks, minimizing municipal breaks, and geographic compactness. Table 3 compares how the enacted Senate plan and the 1,000 computer-simulated plans perform with respect to these various districting criteria.

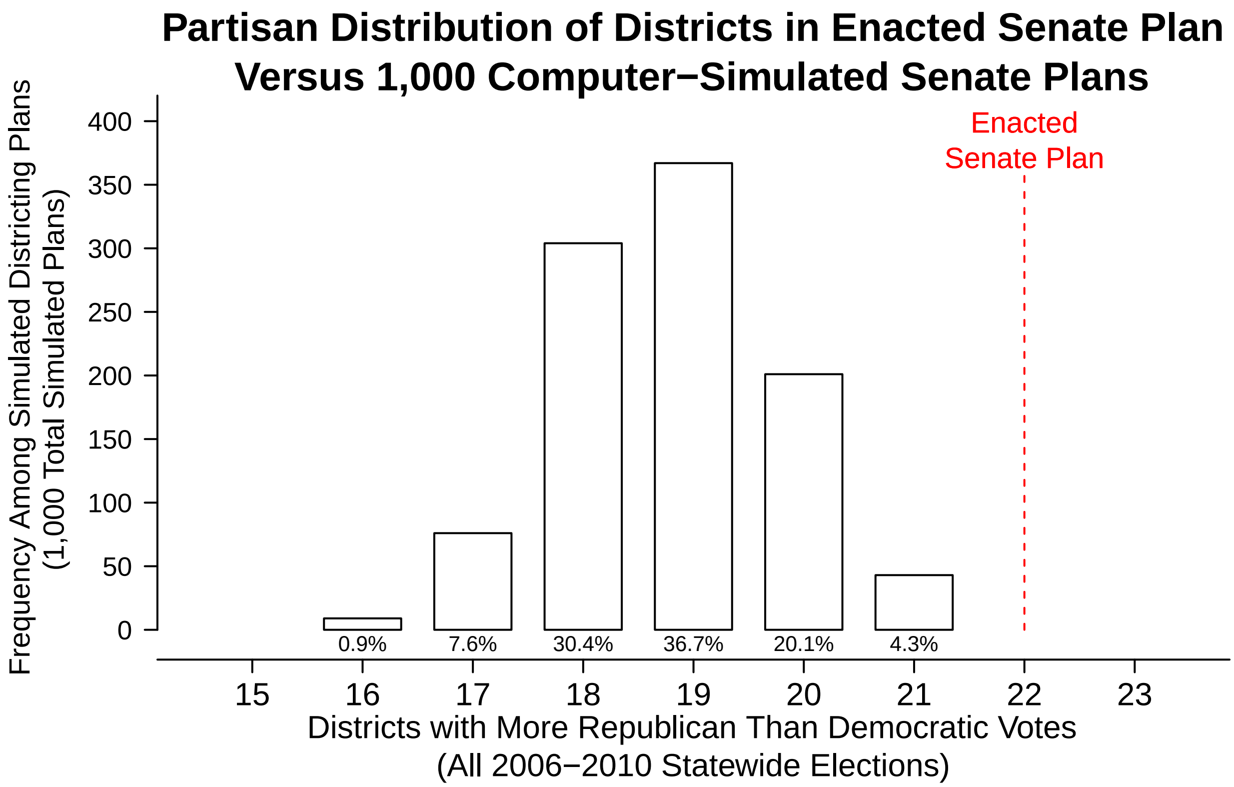
Figure 7 compares the partisanship of the simulated plans to the partisanship of the enacted Senate plan. Specifically, Figure 7 uses all statewide elections during 2006-2010 (upper histogram) and during 2012-2016 (lower histogram) to measure the number of Republican-leaning districts created by the 1,000 simulated plans. As measured by the 2006-2010 statewide election results as a baseline, the simulated plans all create from 16 to 21 Republican districts out of 38 total districts; the vast majority of simulated plans create 18 to 20 Republican districts. Using the 2012-2016 statewide elections as a baseline, the simulated plans all create from 18 to 22 Republican districts out of 38 total districts; the vast majority of simulated plans create 19 or 20 Republican districts.

By contrast, the enacted Senate plans contains 22 Republican districts, as measured by the 2006-2010 elections, and 24 Republican districts, as measured by the 2012-2016 elections. In each histogram, the red dashed line indicates the number of Republican districts created by the enacted Senate plan. The finding that none of the 1,000 computer-simulated plans ever reaches as many Republican districts as the enacted plan allows me to conclude, with over 99.9% certainty, that the enacted plan is a partisan outlier that intentionally created a pro-Republican partisan outcome.

Table 3:
Comparison of the Enacted Senate Plan (Act 129 of 2011) to Computer-Simulated Senate Plans

	Enacted Senate Pla (Public Act 129 of 2011):	1,000 Computer-Simulated Senate Maps:
Number of County Breaks, as described by MCL 4.261:	6	5 (1,000 simulated maps)
Number of Counties Divided into Multiple Districts (Excludes Wayne County):	6	5 (1,000 simulated maps)
Number of Municipal Breaks, as described by MCL 4.261 (Excluding Detroit and Brownstown Twp):	5	0 (1,000 simulated maps)
Number of Municipalities Divided into Multiple Districts (Excluding Detroit):	6	1 (1,000 simulated maps)
<u>Compactness as Defined by MCL 4.261(j)</u> Total Land Area Within Districts' Circumscribing Circles but Outside of their Respective Districts (Lower Area Indicates Greater Compactness):	138,893 Sq. Km.	96,030 to 126,774 Sq. Km.
<u>Compactness as Defined by MCL 4.261(j)</u> Average Ratio of Each District's Land Area to the Land Area Inside the District's Circumscribing Circle (Higher Ratio Indicates Greater Compactness):	0.459	0.477 to 0.503
<u>Compactness, Measured Using Average Reock Score</u> (Higher Score Indicates Greater Compactness):	0.395	0.419 to 0.442
Districts with More Republican than Democratic Votes (All 2006-2010 statewide elections):	22	16 (9 simulated maps) 17 (76 simulated maps) 18 (304 simulated maps) 19 (367 simulated maps) 20 (201 simulated maps) 21 (43 simulated maps)
Districts with More Republican than Democratic Votes (All 2012-2016 statewide elections):	24	18 (123 simulated maps) 19 (454 simulated maps) 20 (346 simulated maps) 21 (75 simulated maps) 22 (2 simulated map)

Figure 7:


Partisan Distribution of Districts in Enacted Senate Plan
Versus 1,000 Computer−Simulated Senate Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
400
350
300
250
200
150
100
50
0
Enacted
Senate Plan
0.9%
7.6%
30.4%
36.7%
20.1%
4.3%
15
16
17
18
19
20
21
22
23
Districts with More Republican Than Democratic Votes
(All 2006−2010 Statewide Elections)

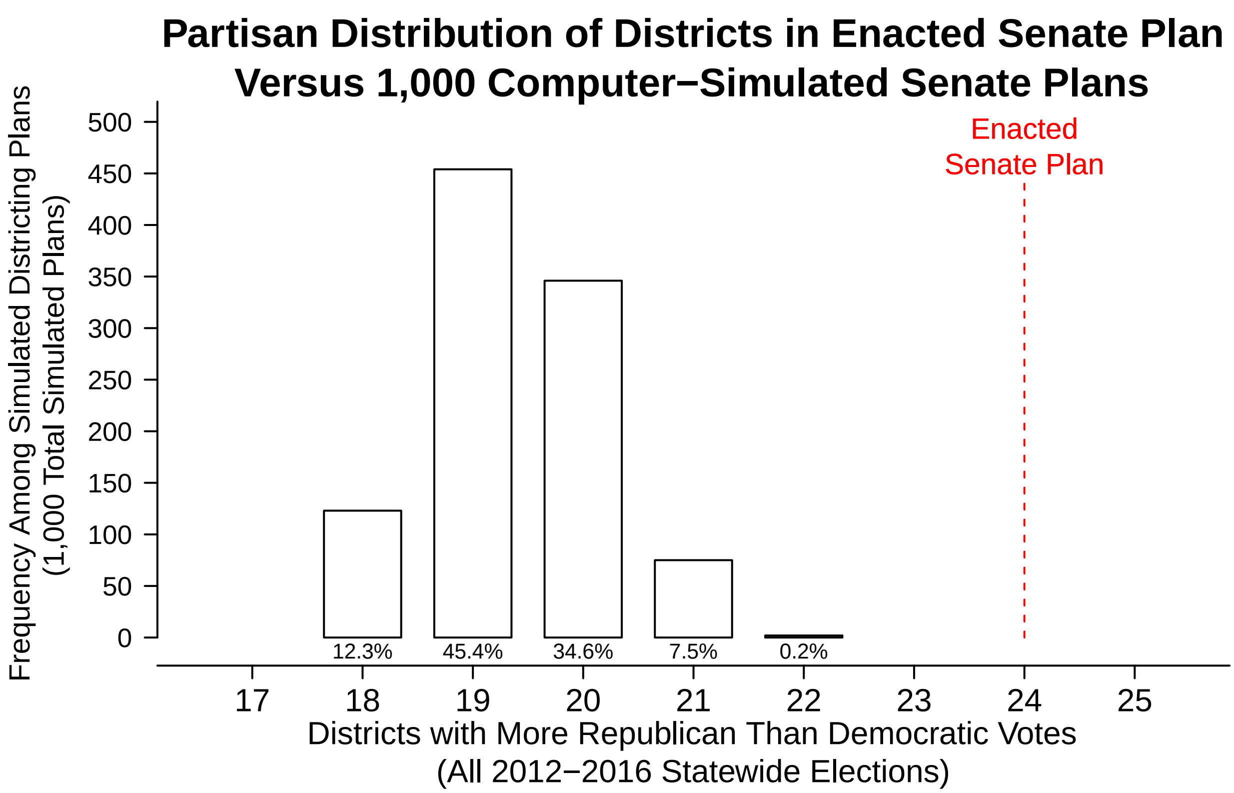
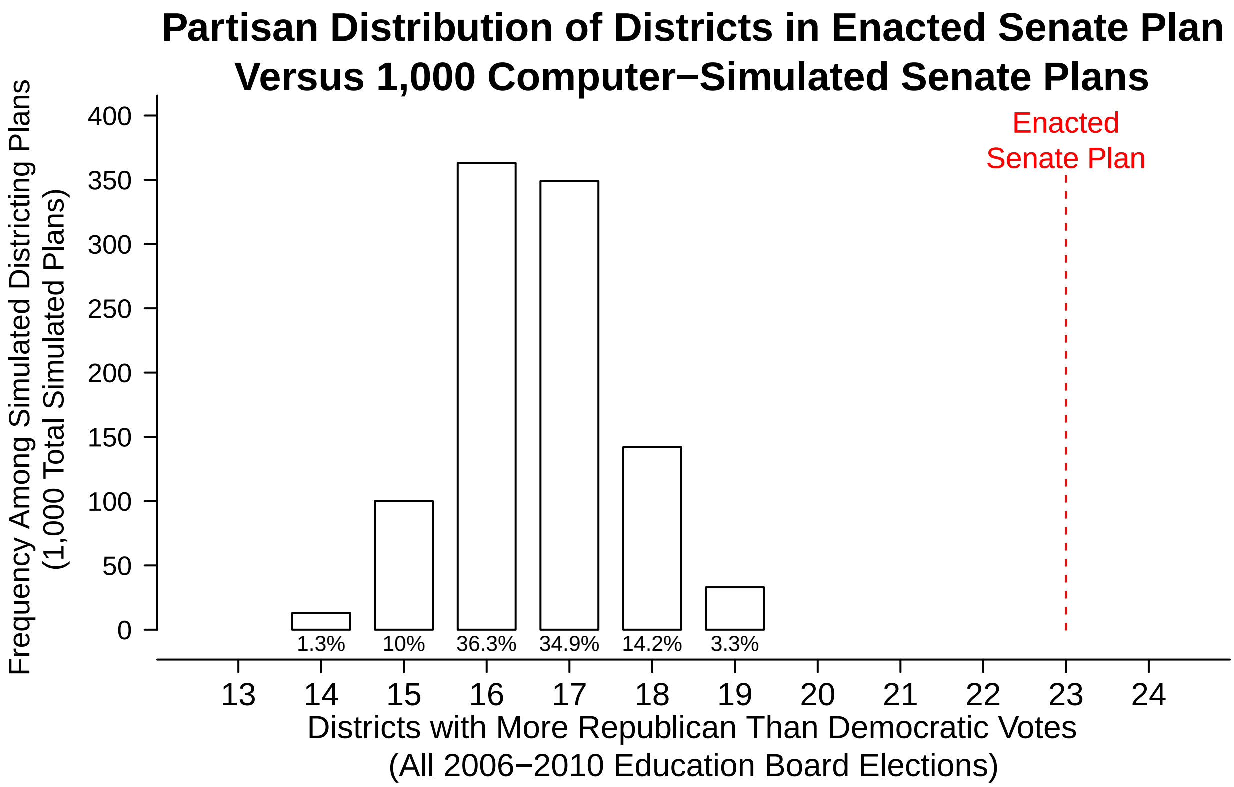

Partisan Distribution of Districts in Enacted Senate Plan
Versus 1,000 Computer−Simulated Senate Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
500
450
400
350
300
250
200
150
100
50
0
Enacted
Senate Plan
12.3%
45.4%
34.6%
7.5%
0.2%
17
18
19
20
21
22
23
24
25
Districts with More Republican Than Democratic Votes
(All 2012−2016 Statewide Elections)

Figure 8:


Partisan Distribution of Districts in Enacted Senate Plan
Versus 1,000 Computer−Simulated Senate Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
400
350
300
250
200
150
100
50
0
Enacted
Senate Plan
1.3%
10%
36.3%
34.9%
14.2%
3.3%
13
14
15
16
17
18
19
20
21
22
23
24
Districts with More Republican Than Democratic Votes
(All 2006−2010 Education Board Elections)

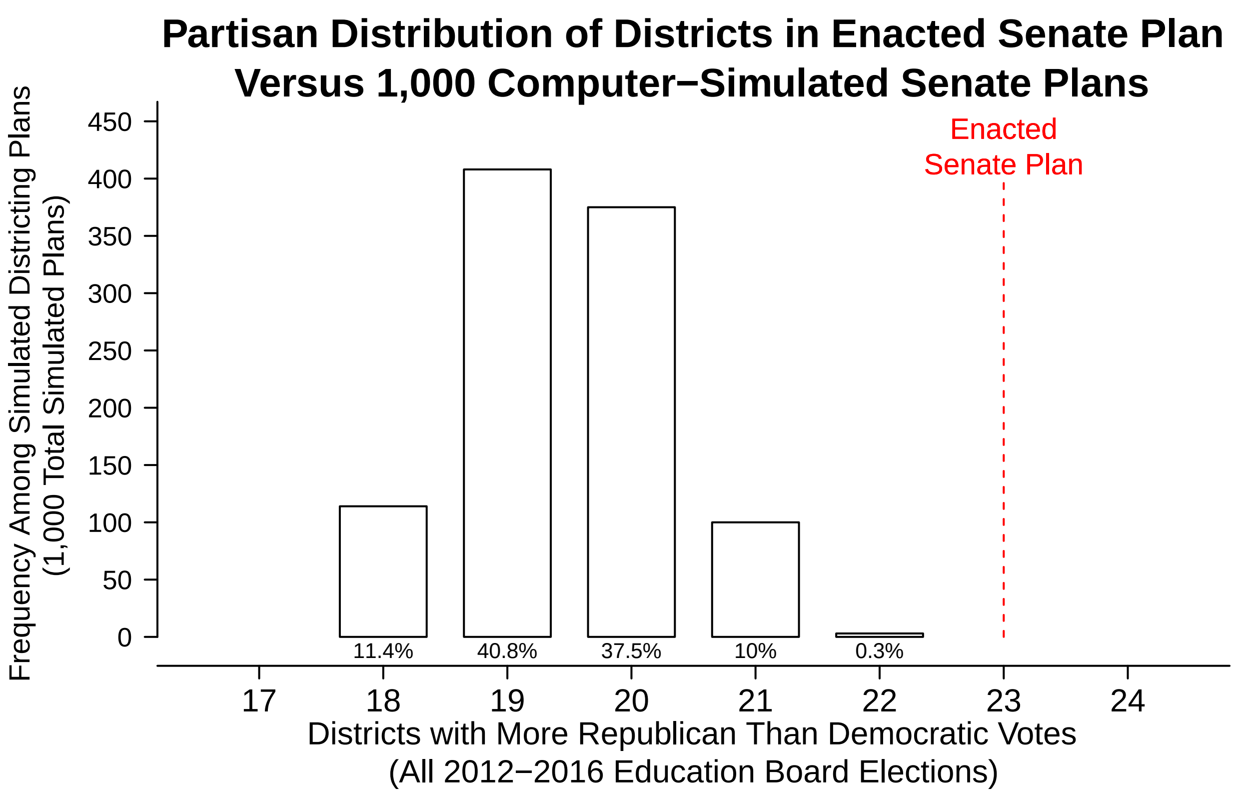

Partisan Distribution of Districts in Enacted Senate Plan
Versus 1,000 Computer−Simulated Senate Plans
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
450
400
350
300
250
200
150
100
50
0
Enacted
Senate Plan
11.4%
40.8%
37.5%
10%
0.3%
17
18
19
20
21
22
23
24
Districts with More Republican Than Democratic Votes
(All 2012−2016 Education Board Elections)

Figure 8 confirms this pro-Republican partisan bias in the enacted Senate plan by analyzing districts using the education and university board elections held during 2006-2010 (upper histogram) and during 2012-2016 (lower histogram) to measure the number of Republican-leaning districts in each plan. As measured by the 2006-2010 statewide election results, the simulated plans all create from 14 to 19 Republican districts out of 38 total districts; the vast majority of simulated plans create 16 or 17 Republican districts. Using the 2012-2016 education and university board elections, the simulated plans all create from 18 to 22 Republican districts out of 38 total districts; the vast majority of simulated plans create 19 or 20 Republican districts.

By contrast, the enacted Senate plan contains 23 Republican districts, as measured by the 2006-2010 education and university board elections, and 23 Republican districts, as measured by the 2012-2016 education and university board elections. In each histogram, the red dashed line indicates the number of Republican districts created by the enacted Senate plan. The finding that none of the 1,000 computer-simulated plans ever reaches the number of Republican districts in the enacted plan allows me to confirm, with over 99.9% statistical certainty, that the enacted plan created a pro-Republican partisan bias, and that the enacted plan is a partisan outlier.

Why did the enacted Senate plan fail to produce geographically compact districts? As Figures 7 – 10 collectively illustrate, the enacted Senate plan is entirely outside the range of all 1,000 simulated maps with respect to both geographic compactness and the partisan distribution of seats.

Collectively, these findings suggest that the enacted Senate plan was drawn under a process in which a partisan goal – creating additional Republican districts – predominated. I am thus able to conclude, with over 99.9% statistical certainty, that the enacted Senate plan created districts less compact than what would have reasonably emerged from a nonpartisan districting process rather than a process driven by partisan intent.

Figure 9:

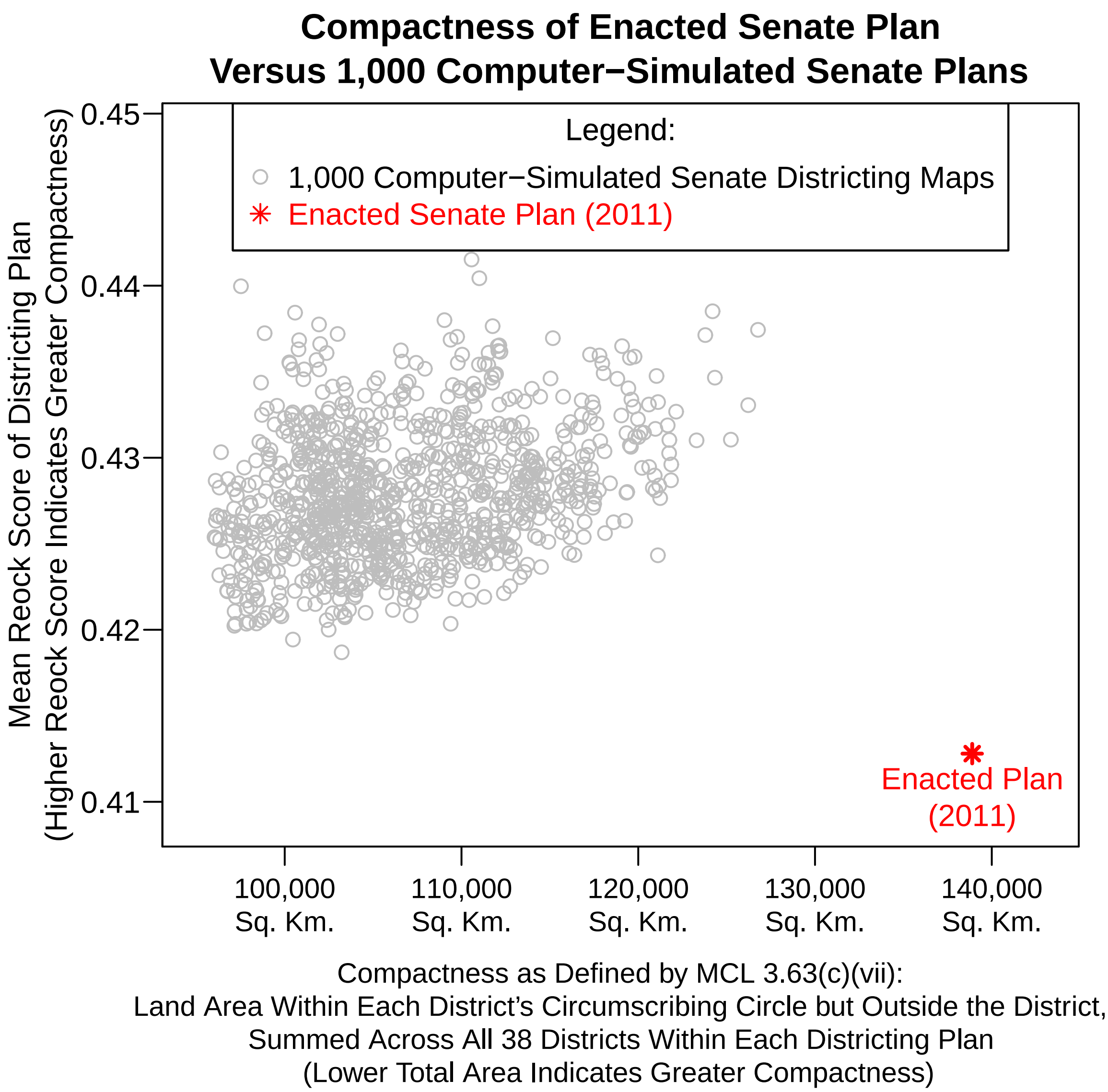
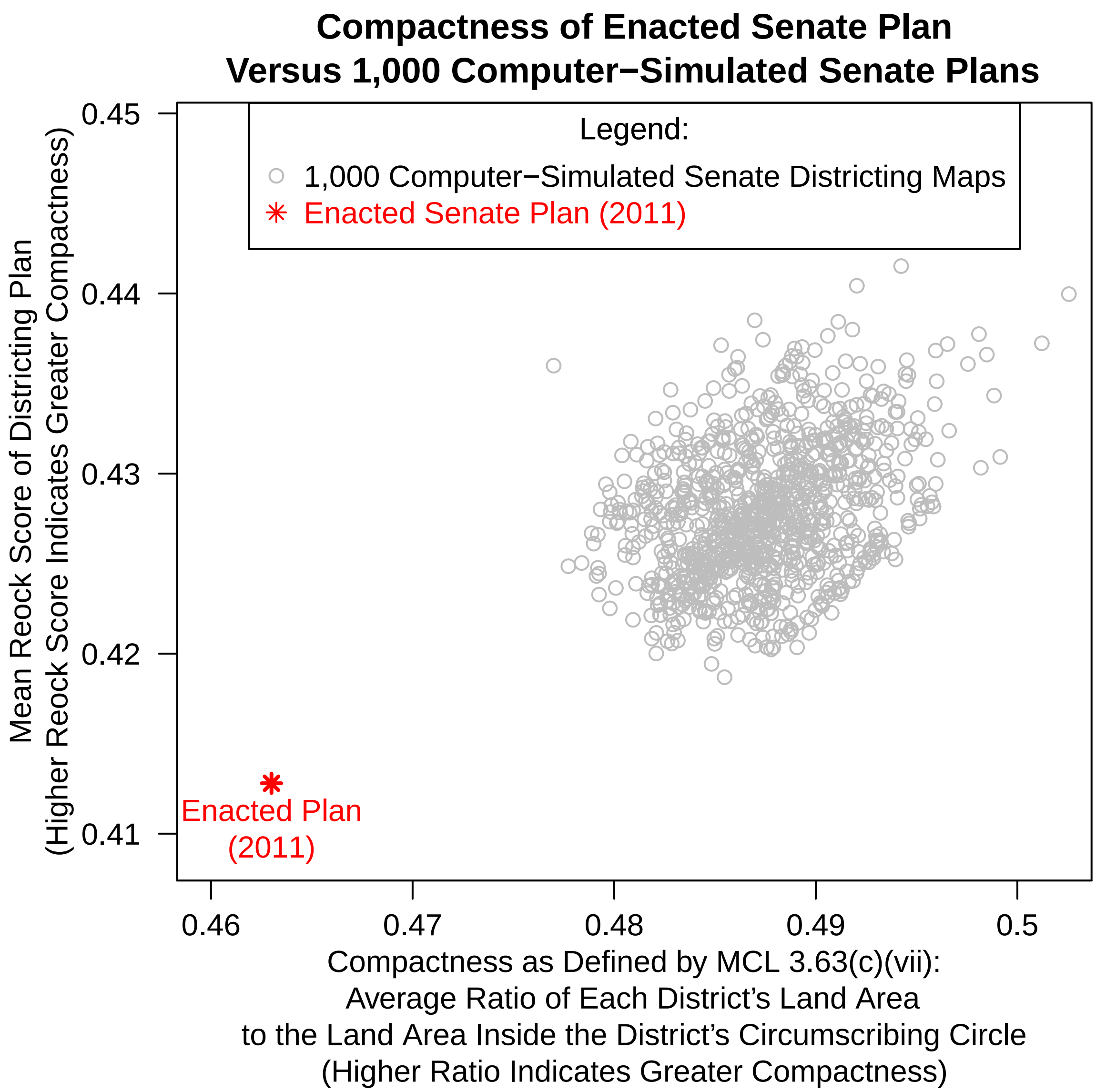

Compactness of Enacted Senate Plan
Versus 1,000 Computer−Simulated Senate Plans
Legend:
1,000 Computer−Simulated Senate Districting Maps
Enacted Senate Plan (2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.45
0.44
0.43
0.42
0.41
Enacted Plan
(2011)
100,000
Sq. Km.
110,000
Sq. Km.
120,000
Sq. Km.
130,000
Sq. Km.
140,000
Sq. Km.
Compactness as Defined by MCL 3.63(c)(vii):
Land Area Within Each District's Circumscribing Circle but Outside the District,
Summed Across All 38 Districts Within Each Districting Plan
(Lower Total Area Indicates Greater Compactness)

Figure 10:


Compactness of Enacted Senate Plan
Versus 1,000 Computer−Simulated Senate Plans
Legend:
1,000 Computer−Simulated Senate Districting Maps
Enacted Senate Plan (2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.45
0.44
0.43
0.42
0.41
Enacted Plan
(2011)
0.46
0.47
0.48
0.49
0.5
Compactness as Defined by MCL 3.63(c)(vii):
Average Ratio of Each District's Land Area
to the Land Area Inside the District's Circumscribing Circle
(Higher Ratio Indicates Greater Compactness)

Robustness Checks Using Alternative Measures of Partisan Bias: Comparing the number of Republican-favoring districts, as measured by recent past statewide elections, is the most comprehensive and statistically valid method of measuring the partisan bias of the enacted Senate plan, as compared to the computer-simulated plans. Counting the number of Republican and Democratic-favoring districts in a plan, as measured using recent statewide elections, is a broad, durable and sufficient measurement of districting plan partisanship, particularly since it is common practice in Michigan to assess the partisanship of districts by aggregating together the results of recent statewide education and university board elections.

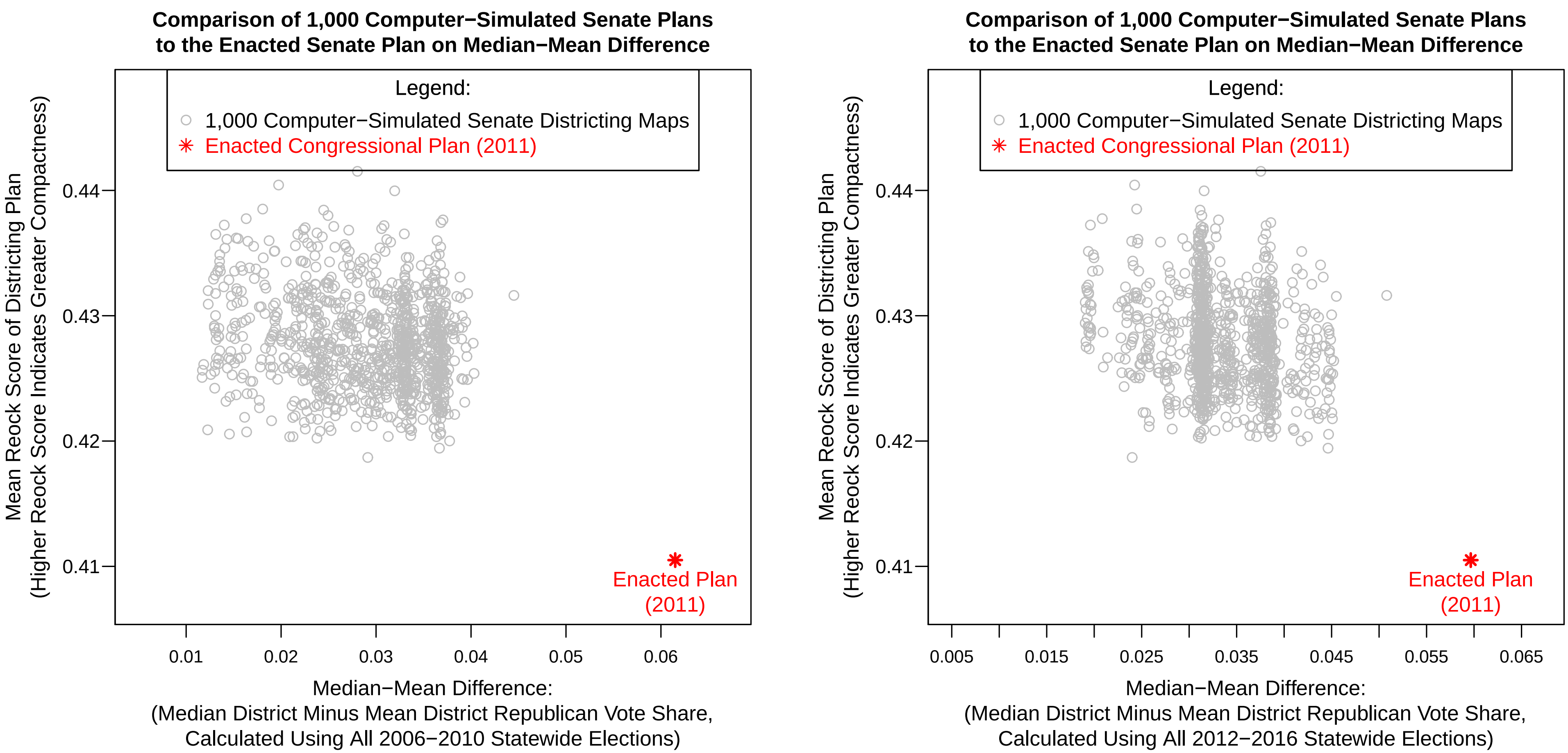
What follows in the remainder of this section, then, is a completely separate set of analyses in which I examine the simulated plans and the enacted Senate plan using two alternative measures of partisanship and electoral bias: The Median-Mean Difference and the Efficiency Gap. These two alternative measures are presented as robustness checks, and the conclusions reached in the previous sections do not depend on these robustness checks. I introduce these alternative measures of districting plan partisanship in order to illustrate the findings of my simulation analysis in more relatable ways and to demonstrate the robustness of these findings.

I first measure the Median-Mean Difference of the enacted Senate plan and then compare it to the Mean-Median Differences of the 1,000 computer-simulated Senate plans. As described earlier in this report, using the aggregated results of Michigan's 2006-2010 statewide elections, the 38 districts in Michigan's enacted Senate plan have a Median-Mean Difference of 6.15%. The enacted plan's districts have a mean Republican vote share of 46.59%, while the median district has a Republican vote share of 52.74%. Thus, the enacted Senate plan has a Median-Mean Difference of 6.15%, indicating that the median district is skewed significantly more Republican than the plan's average district. Similarly, using the results of Michigan's 2012-2016 statewide elections, the Median-Mean Difference of the enacted Senate plan is 5.97%, confirming that the median district is skewed significantly more Republican than the enacted plan's average district. In other words, the enacted plan distributes voters across districts in such a way that most districts are significantly more Republican-leaning than the average Senate district, while Democratic voters are more heavily concentrated in a minority of the Senate districts. This skew in the enacted plan thus creates a significant advantage for Republicans by giving them stronger control over the median district in the enacted Senate plan.

How does this Median-Mean Difference of the enacted plan compare to that of the 1,000 computer-simulated plans? Figure 11 presents comparisons of the enacted Senate plan to the 1,000 computer-simulated plans on their Median-Mean Differences. The left side of this Figure calculates the Median-Mean Difference using the aggregated results of Michigan's 2006-2010 statewide elections, while the right side of the Figure uses the aggregated results of the 2012-2016 statewide elections. In both diagrams, the horizontal axis depicts the Median-Mean Difference of each plan, while the vertical axis depicts the Reock score of each plan, measuring the plan's geographic compactness. In each diagram, the red star represents the enacted Senate plan, while the gray circles represent the 1,000 computer-simulated plans.

Using either set of elections, it is very clear that the enacted Senate plan is significantly more skewed in favor of Republicans than every single one of the 1,000 computer-simulated plans. Almost all of the computer-simulated plans have a Median-Mean Difference between 1.0% to 4.0%, using the 2006-2010 statewide elections, and between 1.7% to 4.5%, using the 2012-2016 statewide elections. Not a single simulated plan comes even close to the enacted plan's extreme Median-Mean Difference of 6.15%, using the 2006-2010 statewide elections, and 5.97%, using the 2012-2016 statewide elections. I thus conclude, with extremely strong statistical certainty, that the enacted Senate plan's extreme Median-Mean Difference is clearly not the result of Michigan's natural political geography, combined with the application of Michigan's statutory redistricting guidelines. It is the result of partisan intent.

Figure 11:

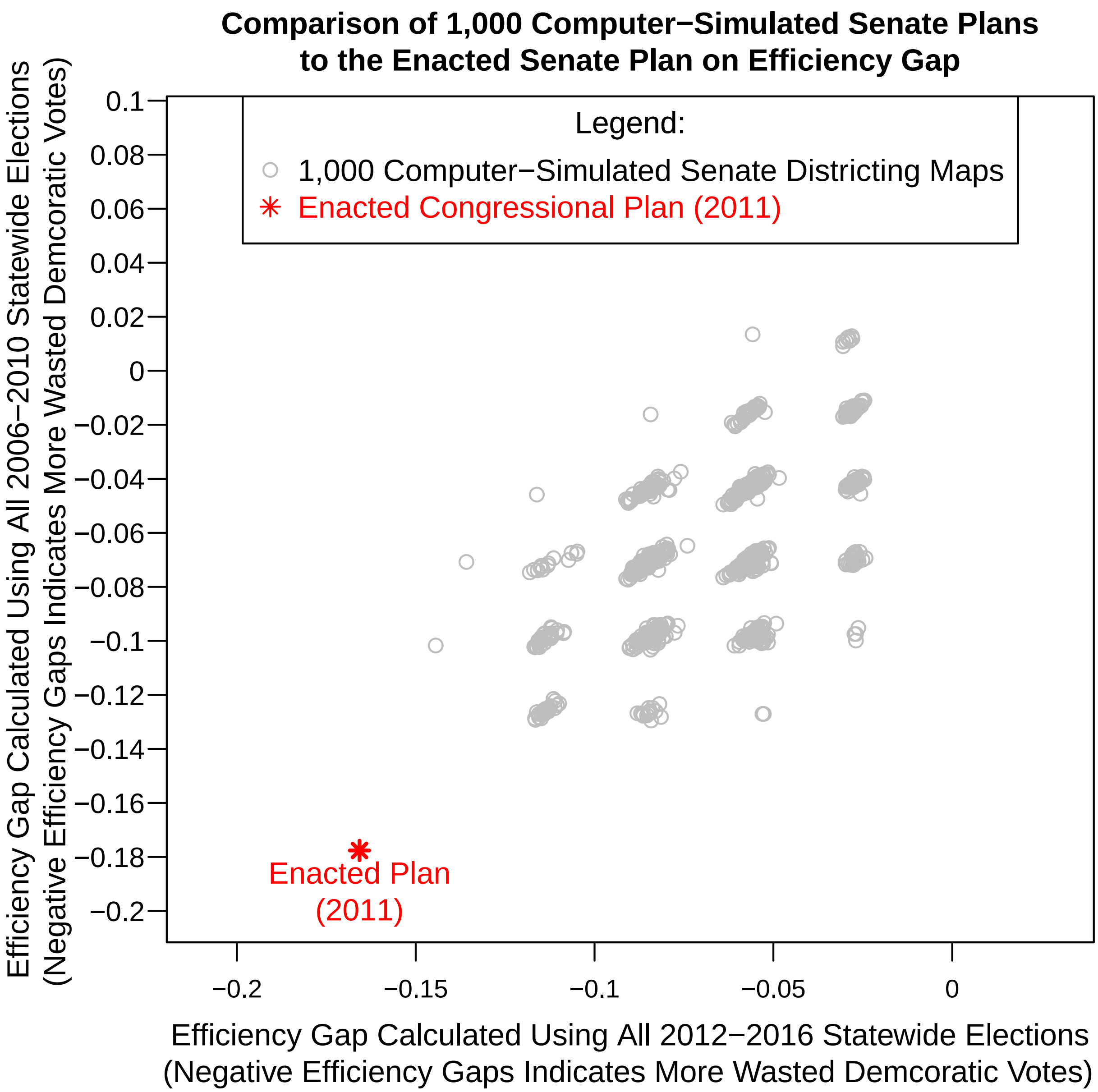

Comparison of 1,000 Computer−Simulated Senate Plans to the Enacted Senate Plan on Median−Mean Difference
Legend:
1,000 Computer−Simulated Senate Districting Maps
Enacted Congressional Plan (2011)
Mean Reock Score of Districting Plan (Higher Reock Score Indicates Greater Compactness)
0.44
0.43
0.42
0.41
Enacted Plan (2011)
0.01
0.02
0.03
0.04
0.05
0.06
Median−Mean Difference: (Median District Minus Mean District Republican Vote Share, Calculated Using All 2006−2010 Statewide Elections)
Comparison of 1,000 Computer−Simulated Senate Plans to the Enacted Senate Plan on Median−Mean Difference
Legend:
1,000 Computer−Simulated Senate Districting Maps
Enacted Congressional Plan (2011)
Mean Reock Score of Districting Plan (Higher Reock Score Indicates Greater Compactness)
0.44
0.43
0.42
0.41
Enacted Plan (2011)
0.005
0.015
0.025
0.035
0.045
0.055
0.065
Median−Mean Difference: (Median District Minus Mean District Republican Vote Share, Calculated Using All 2012−2016 Statewide Elections)

The fact that the 1,000 simulated plans in Figure 11 all produce a small but positive Median-Mean Difference results, at least in part, from the fact that, as noted earlier, the simulation algorithm simply freezes Senate Districts 1 through 7 (covering Detroit City and Wayne County) from the enacted plan, without attempting to draw these seven districts' boundaries in a partisan-neutral manner adhering to the MCL § 4.261 redistricting guidelines. The small Median-Mean Differences in the computer-simulated plans may also partially reflect a modest skew in Michigan's voter geography that slightly benefits the Republicans in districting. This modest skew in the simulated districting plans may result naturally from Democratic voters' tendency to cluster in urban areas of Michigan, as I have explained in my previous academic research.[7] But more importantly, even when combined with the skew from freezing majority-minority districts, the range of this natural skew, as shown in Figure 11, is always much smaller than the extreme 6.15% and 5.97% Median-Mean Differences observed in the enacted Senate plan. Hence, these results confirm the main finding that the enacted plan creates an extreme partisan outcome that cannot be explained by Michigan's voter geography or by the application of the MCL § 4.261 redistricting guidelines. Instead, the extremity of the enacted plan's Median-Mean Difference can only be explained by a districting process that pursued a partisan goal in the drawing of districts.

Next, I compare the enacted Senate plan to the 1,000 computer-simulated Senate plans using the efficiency gap. Figure 12 illustrates these efficiency gap calculations: The vertical axis depicts each plan's efficiency gap using the 2006-2010 statewide elections, while the horizontal axis depicts each plan's efficiency gap using the 2012-2016 statewide elections. The 1,000 gray circles in this Figure represent the computer-simulated districting plan, while the red star represents the enacted Senate plan.

[7] Jowei Chen and Jonathan Rodden, 2013. "Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures" *Quarterly Journal of Political Science*, 8(3): 239-269; Jowei Chen and David Cottrell, 2016. "Evaluating Partisan Gains from Congressional Gerrymandering: Using Computer Simulations to Estimate the Effect of Gerrymandering in the U.S. House." *Electoral Studies*, Vol. 44, No. 4: 329-430.

Figure 12


Comparison of 1,000 Computer−Simulated Senate Plans
to the Enacted Senate Plan on Efficiency Gap
Legend:
1,000 Computer−Simulated Senate Districting Maps
Enacted Congressional Plan (2011)
Enacted Plan
(2011)
Efficiency Gap Calculated Using All 2006−2010 Statewide Elections
(Negative Efficiency Gaps Indicates More Wasted Demcoratic Votes)
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
−0.12
−0.14
−0.16
−0.18
−0.2
−0.2
−0.15
−0.1
−0.05
0
Efficiency Gap Calculated Using All 2012−2016 Statewide Elections
(Negative Efficiency Gaps Indicates More Wasted Demcoratic Votes)

First, this Figure reveals that most of the 1,000 simulated districting plans are reasonably neutral with respect to electoral bias, as measured by the efficiency gap. Using either set of elections, over half of the simulated plans exhibit an efficiency gap within 6% of zero, indicating minimal electoral bias in favor of either party. Not a single simulated plan exhibits an efficiency gap greater than 15%. These patterns illustrate that a non-partisan districting process very commonly produces a neutral Senate plan with minimal electoral bias, as measured by efficiency gap.

Second, it is also important to note that the computer simulations produce plans with both slightly positive and negative efficiency gaps. But the broader, more striking finding in this analysis is that over one-half of the simulated plans produced by the partisan-neutral simulation algorithm following traditional districting criteria are within 6% of a zero efficiency gap. Hence, it is clearly not difficult to create a map that is relatively unbiased according to the efficiency gap measure. To produce a map with significant electoral bias deviating by over 15% from a zero efficiency gap, however, would require extraordinary and deliberate partisan map-drawing efforts.

Third, Michigan's enacted Senate plan, denoted in Figure 12 as a red star, produces an efficiency gap that is extremely inconsistent with and outside of the entire range of the 1,000 computer-simulated plans. The enacted plan creates an efficiency gap of -17.8% using the 2006-2010 statewide elections and -16.6% using the 2012-2016 statewide elections, indicating that the plan consistently results in significantly more wasted Democratic votes than wasted Republican votes. Thus, the level of electoral bias in the enacted Senate plan is not only entirely outside of the range produced by the simulated plans, the enacted plan's efficiency gap is far more biased than even the most biased of the 1,000 simulated plans. The improbable nature of the enacted Senate plan's efficiency gap allows us to conclude with overwhelmingly high statistical certainty that the enacted Senate plan is a partisan outlier.

Comparison of Simulated House Plans to the Enacted House Plan

To evaluate Michigan's enacted House Plan, I produced and analyzed a set of 1,000 simulated House plans using the computer simulation algorithm. As described earlier, the algorithm strictly follows the five non-partisan redistricting guidelines detailed in MCL § 4.261: Contiguity, equalization of district populations within the thresholds mandated by MCL § 4.261, minimizing county breaks, minimizing municipal breaks, and geographic compactness. Table 4 compares how the enacted House plan and the 1,000 computer-simulated plans perform with respect to these various districting criteria.

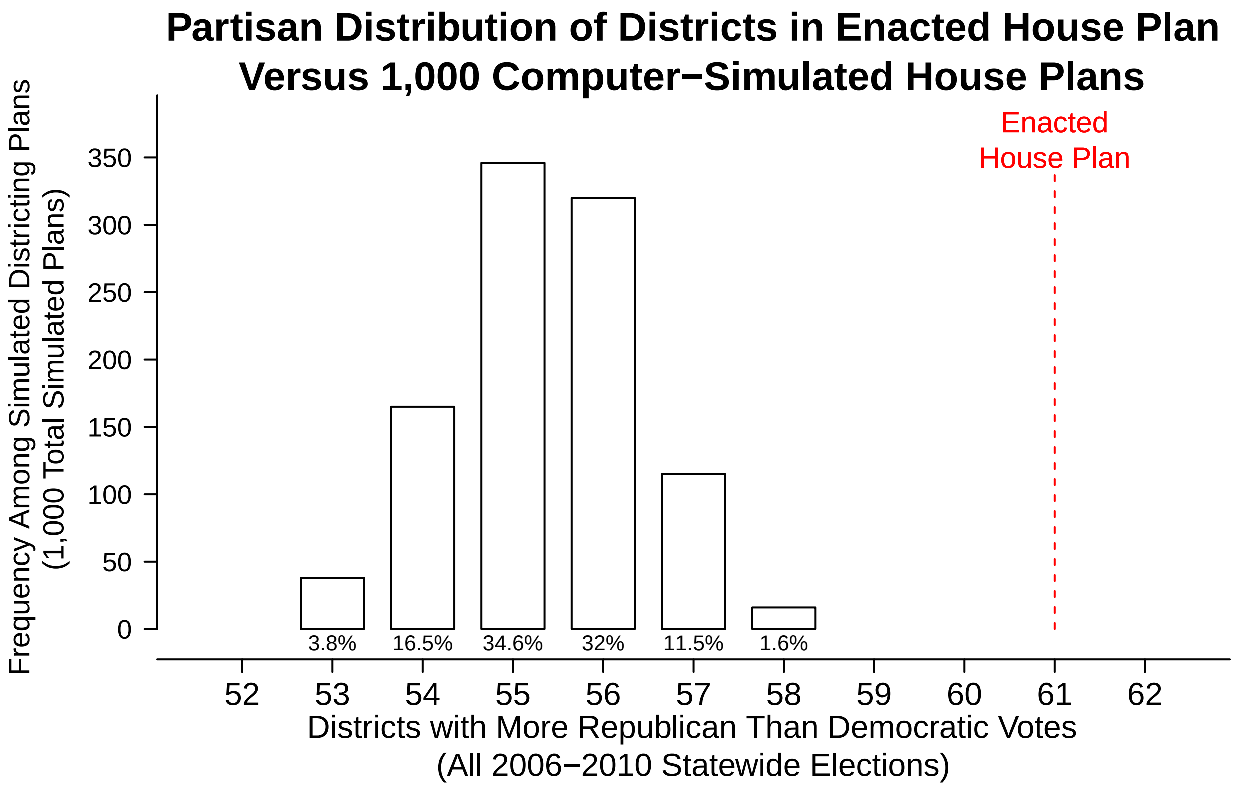
Figure 13 compares the partisanship of the simulated plans to the partisanship of the enacted House plan. Specifically, Figure 13 uses all statewide elections during 2006-2010 (upper histogram) and during 2012-2016 (lower histogram) to measure the number of Republican-leaning districts created by the 1,000 simulated plans. As measured by the 2006-2010 statewide election results, the simulated plans all create from 53 to 58 Republican districts out of 110 total districts; the vast majority of simulated plans create 54 to 56 Republican districts. Using the 2012-2016 statewide elections as a baseline, the simulated plans all create from 56 to 60 Republican districts out of 110 total districts; the vast majority of simulated plans create 58 Republican districts.

By contrast, the enacted House plans contains 61 Republican districts, as measured by the 2006-2010 elections, and 61 Republican districts, as measured by the 2012-2016 elections. In each histogram, the red dashed line indicates the number of Republican districts created by the enacted House plan. The finding that none of the 1,000 computer-simulated plans ever reaches the enacted plan's creation of 61 Republican districts allows me to conclude, with over 99.9% statistical certainty, that the enacted plan is a partisan outlier which intentionally created a pro-Republican partisan outcome.

Table 4:
Comparison of the Enacted House Plan (Act 129 of 2011) to Computer-Simulated House Plans

	Enacted House Plan (Public Act 129 of 2011):	1,000 Computer-Simulated House Maps:
Number of County Breaks, as described by MCL 4.261:	17	14 (1,000 simulated maps)
Number of Counties Divided into Multiple Districts (Including Wayne County):	28	27 (1,000 simulated maps)
Number of Municipal Breaks, as described by MCL 4.261 (Excluding Detroit):	24	13 (300 simulated maps) 14 (700 simulated maps)
Number of Municipalities Divided into Multiple Districts (Excluding Detroit):	24	14 (994 simulated maps) 15 (6 simulated maps)
<u>Compactness as Defined by MCL 4.261(j)</u> Total Land Area Within Districts' Circumscribing Circles but Outside of their Respective Districts (Lower Area Indicates Greater Compactness):	176,224 Sq. Km.	149,055 to 172,776 Sq. Km.
<u>Compactness as Defined by MCL 4.261(j)</u> Average Ratio of Each District's Land Area to the Land Area Inside the District's Circumscribing Circle (Higher Ratio Indicates Greater Compactness):	0.447	0.448 to 0.468
<u>Compactness, Measured Using Average Reock Score</u> (Higher Score Indicates Greater Compactness):	0.415	0.418 to 0.435
Districts with More Republican than Democratic Votes (All 2006-2010 statewide elections):	61	53 (38 simulated maps) 54 (165 simulated maps) 55 (346 simulated maps) 56 (320 simulated maps) 57 (115 simulated maps) 58 (16 simulated maps)
Districts with More Republican than Democratic Votes (All 2012-2016 statewide elections):	61	56 (1 simulated maps) 57 (81 simulated maps) 58 (749 simulated maps) 59 (167 simulated maps) 60 (2 simulated maps)

Figure 13:


Partisan Distribution of Districts in Enacted House Plan
Versus 1,000 Computer−Simulated House Plans
Enacted
House Plan
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
0
50
100
150
200
250
300
350
3.8%
16.5%
34.6%
32%
11.5%
1.6%
52
53
54
55
56
57
58
59
60
61
62
Districts with More Republican Than Democratic Votes
(All 2006−2010 Statewide Elections)

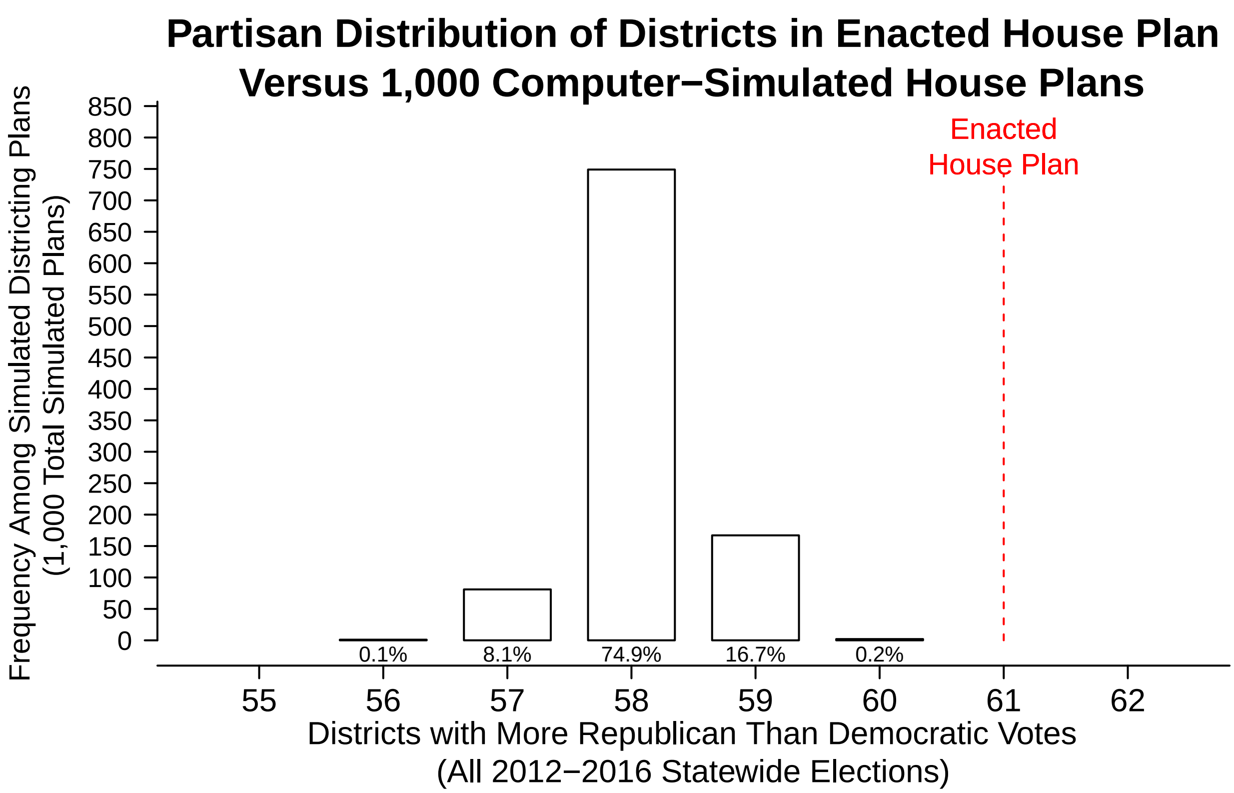
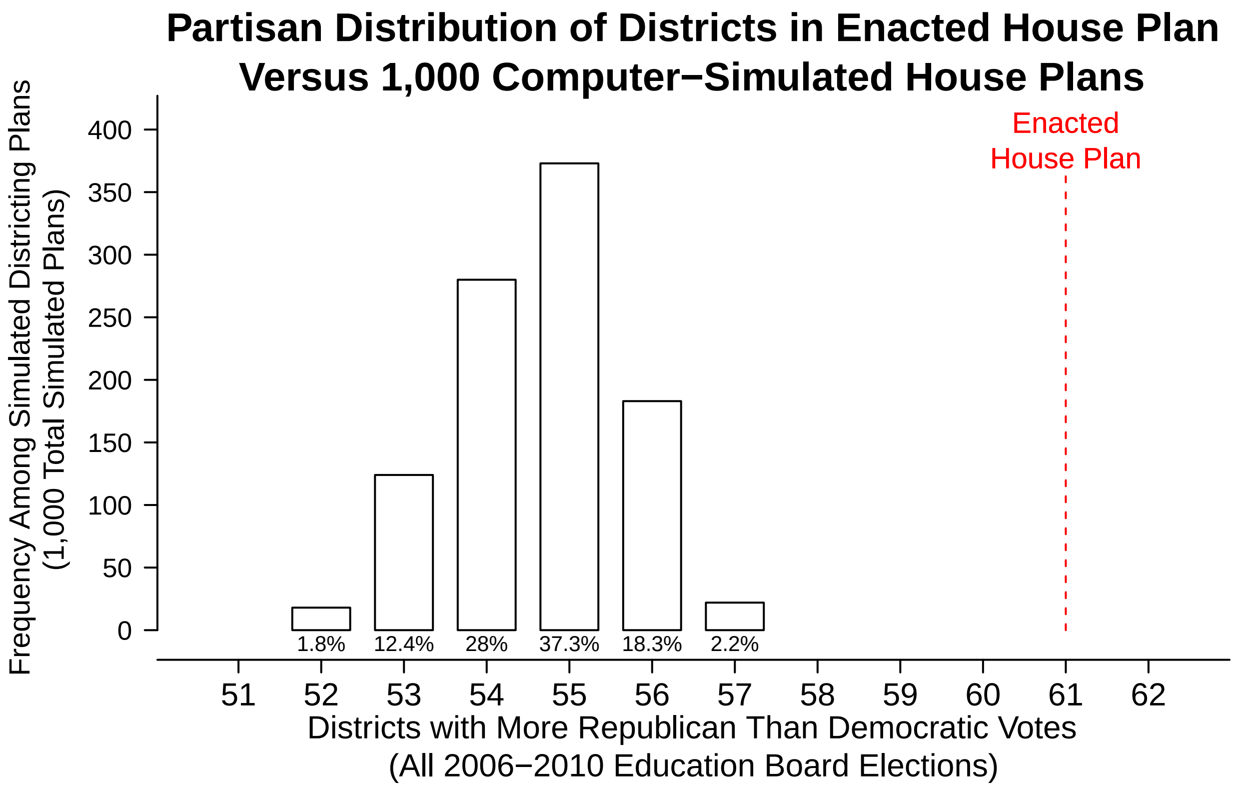

Partisan Distribution of Districts in Enacted House Plan
Versus 1,000 Computer−Simulated House Plans
Enacted
House Plan
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
850
0.1%
8.1%
74.9%
16.7%
0.2%
55
56
57
58
59
60
61
62
Districts with More Republican Than Democratic Votes
(All 2012−2016 Statewide Elections)

Figure 14:


Partisan Distribution of Districts in Enacted House Plan
Versus 1,000 Computer−Simulated House Plans
Enacted
House Plan
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
0
50
100
150
200
250
300
350
400
1.8%
12.4%
28%
37.3%
18.3%
2.2%
51
52
53
54
55
56
57
58
59
60
61
62
Districts with More Republican Than Democratic Votes
(All 2006−2010 Education Board Elections)

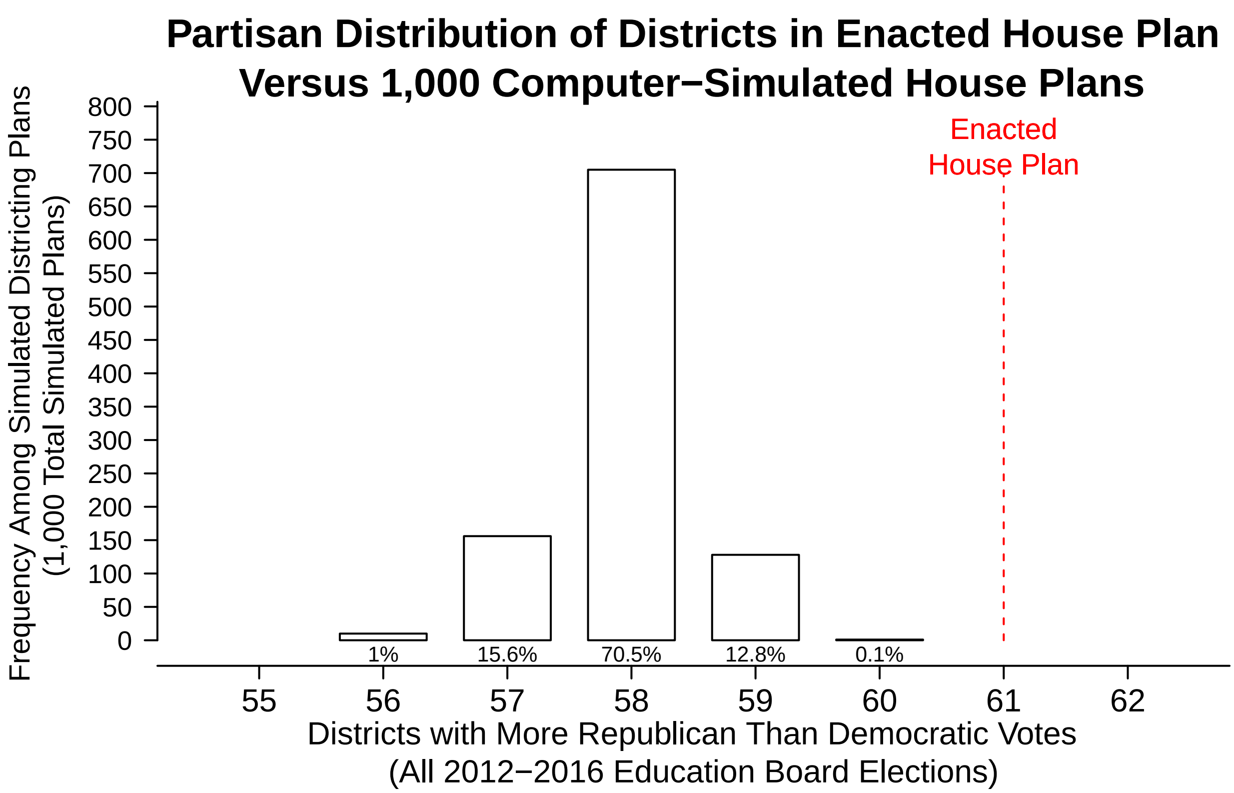

Partisan Distribution of Districts in Enacted House Plan
Versus 1,000 Computer−Simulated House Plans
Enacted
House Plan
Frequency Among Simulated Districting Plans
(1,000 Total Simulated Plans)
0
50
100
150
200
250
300
350
400
450
500
550
600
650
700
750
800
1%
15.6%
70.5%
12.8%
0.1%
55
56
57
58
59
60
61
62
Districts with More Republican Than Democratic Votes
(All 2012−2016 Education Board Elections)

Figure 14 confirms this pro-Republican partisan bias in the enacted House plan by analyzing districts using the education and university board elections held during 2006-2010 (upper histogram) and during 2012-2016 (lower histogram) to measure the number of Republican-leaning districts in each plan. As measured by the 2006-2010 election results as a baseline, the simulated plans all create from 52 to 57 Republican districts out of 110 total districts; the vast majority of simulated plans create 53 to 56 Republican districts. Using the 2012-2016 education and university board elections as a baseline, the simulated plans all create from 56 to 60 Republican districts out of 110 total districts; the vast majority of simulated plans create 58 Republican districts.

By contrast, the enacted House plan contains 61 Republican districts, as measured by the 2006-2010 education and university board elections, and 61 Republican districts, as measured by the 2012-2016 education and university board elections. In each histogram, the red dashed line indicates the number of Republican districts created by the enacted House plan. The finding that none of the 1,000 computer-simulated plans ever reaches the number of Republican districts in the enacted plan allows me to confirm, with over 99.9% statistical certainty, that the enacted plan is a partisan outlier which contains a pro-Republican partisan bias.

Why did the enacted House plan fail to produce geographically compact districts? As Figures 13 – 16 collectively illustrate, the enacted House plan is entirely outside the range of all 1,000 simulated maps with respect to both geographic compactness and the partisan distribution of seats.

Collectively, these findings suggest that the enacted House plan was drawn under a process in which a partisan goal – creating additional Republican districts – predominated. I thus am able to conclude, with over 99.9% statistical certainty, that the enacted House plan created districts less compact than what would have reasonably emerged from a nonpartisan districting process rather than a process driven by partisan intent.

Figure 15:

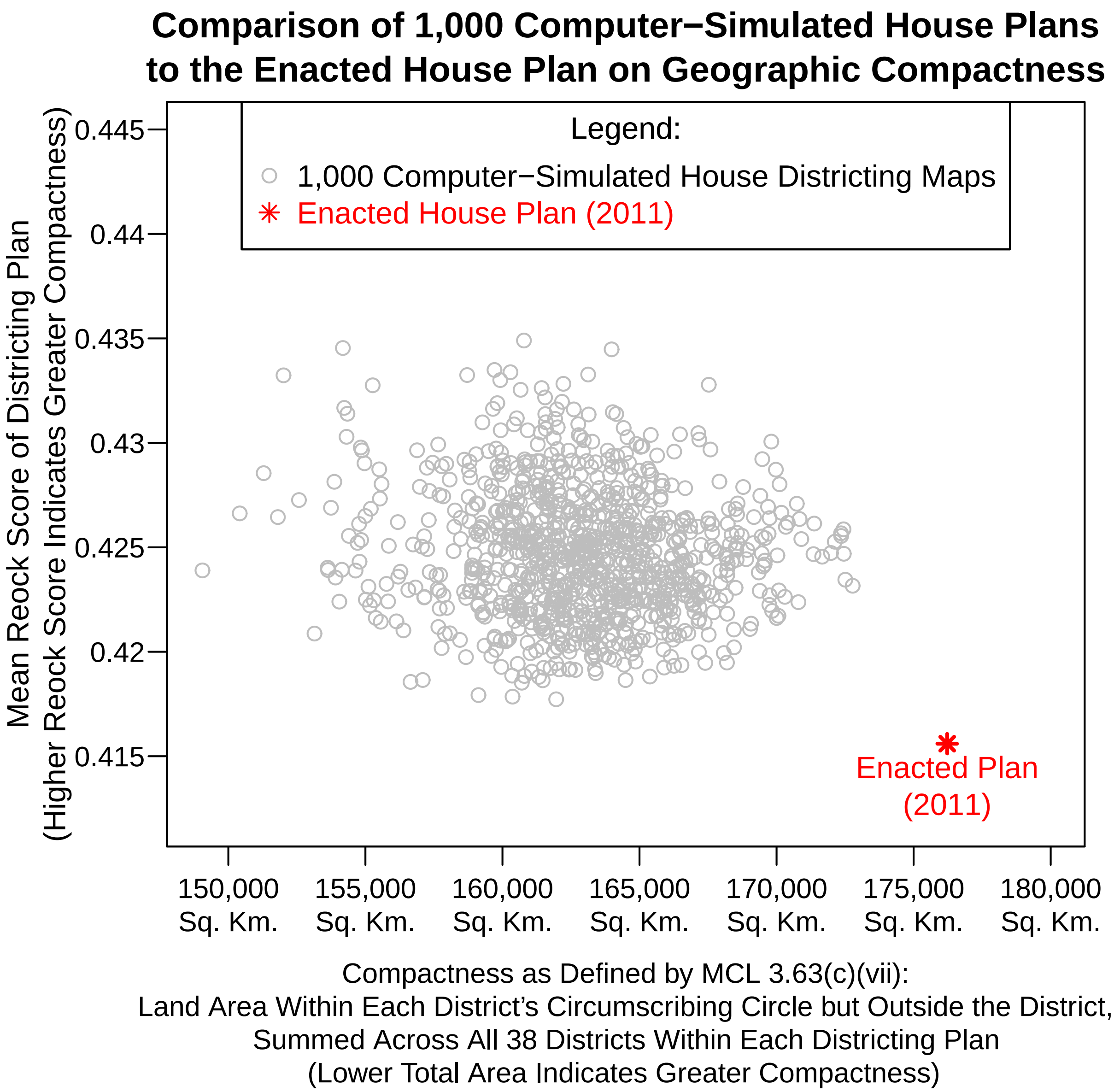
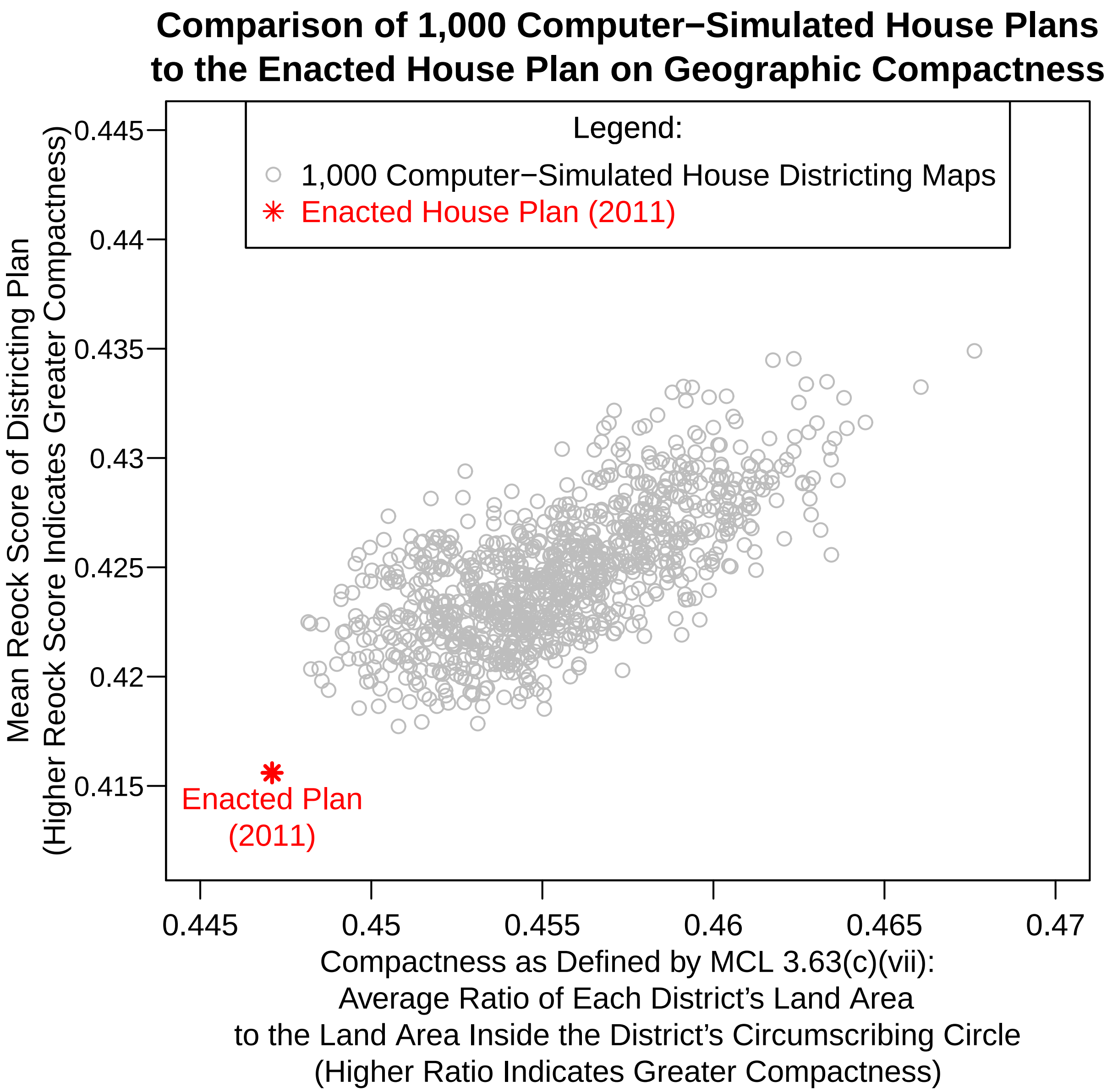

Comparison of 1,000 Computer−Simulated House Plans
to the Enacted House Plan on Geographic Compactness
Legend:
1,000 Computer−Simulated House Districting Maps
Enacted House Plan (2011)
Enacted Plan
(2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.445
0.44
0.435
0.43
0.425
0.42
0.415
150,000 Sq. Km.
155,000 Sq. Km.
160,000 Sq. Km.
165,000 Sq. Km.
170,000 Sq. Km.
175,000 Sq. Km.
180,000 Sq. Km.
Compactness as Defined by MCL 3.63(c)(vii):
Land Area Within Each District's Circumscribing Circle but Outside the District,
Summed Across All 38 Districts Within Each Districting Plan
(Lower Total Area Indicates Greater Compactness)

Figure 16:


Comparison of 1,000 Computer−Simulated House Plans
to the Enacted House Plan on Geographic Compactness
Legend:
1,000 Computer−Simulated House Districting Maps
Enacted House Plan (2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.445
0.44
0.435
0.43
0.425
0.42
0.415
Enacted Plan
(2011)
0.445
0.45
0.455
0.46
0.465
0.47
Compactness as Defined by MCL 3.63(c)(vii):
Average Ratio of Each District's Land Area
to the Land Area Inside the District's Circumscribing Circle
(Higher Ratio Indicates Greater Compactness)

Robustness Checks Using Alternative Measures of Partisan Bias: Comparing the number of Republican-favoring districts, as measured by recent past statewide elections, is the most comprehensive and statistically valid method of measuring the partisan bias of the enacted House plan, as compared to the computer-simulated plans. Counting the number of Republican and Democratic-favoring districts in a plan, as measured using recent statewide elections, is a broad, durable and sufficient measurement of districting plan partisanship, particularly since it is common practice in Michigan to assess the partisanship of districts by aggregating together the results of recent statewide education and university board elections.

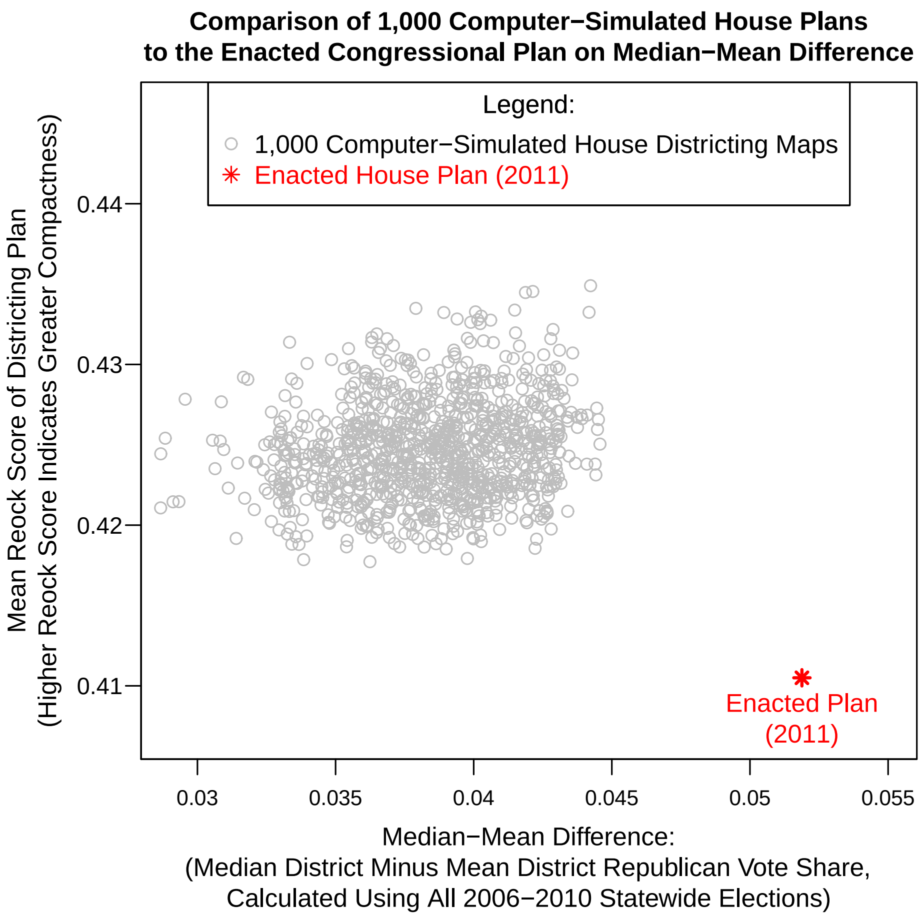
What follows in the remainder of this section, then, is a completely separate set of analyses in which I examine the simulated plans and the enacted House plan using two alternative measures of partisanship and electoral bias: The Median-Mean Difference and the Efficiency Gap. These two alternative measures are presented as robustness checks, and the conclusions reached in the previous sections do not depend on these robustness checks. I introduce these alternative measures of districting plan partisanship in order to illustrate the findings of my simulation analysis in more relatable ways -- and to demonstrate the robustness of these findings.

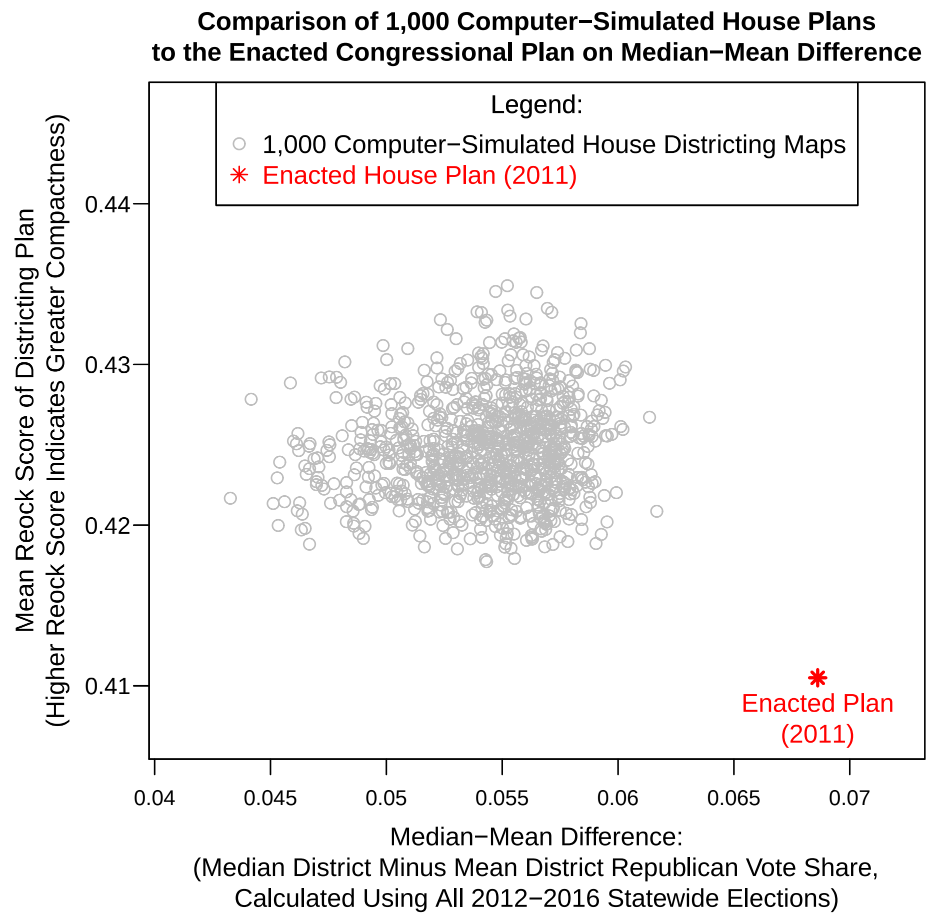
I first measure the Median-Mean Difference of the enacted House plan and then compare it to the Mean-Median Differences of the 1,000 computer-simulated House plans. As described earlier in this report, using the aggregated results of Michigan's 2006-2010 statewide elections, the 110 districts in Michigan's enacted House plan have a Median-Mean Difference of 5.19%. The enacted plan's districts have a mean Republican vote share of 46.22%, while the median district has a Republican vote share of 51.41%. Thus, the enacted House plan has a Median-Mean Difference of 5.19%, indicating that the median district is skewed significantly more Republican than the plan's average district. Similarly, using the results of Michigan's 2012-2016 statewide elections, the Median-Mean Difference of the enacted House plan is 6.86%, confirming that the median district is skewed significantly more Republican than the enacted plan's average district. In other words, the enacted plan distributes voters across districts in such a way that most districts are significantly more Republican-leaning than the average House district, while Democratic voters are more heavily concentrated in a minority of the House districts. This skew in the enacted plan thus creates a significant advantage for Republicans by giving them stronger control over the median district in the enacted House plan.

How does this Median-Mean Difference of the enacted plan compare to that of the 1,000 computer-simulated plans? Figure 17 presents comparisons of the enacted House plan to the 1,000 computer-simulated plans on their Median-Mean Differences. The left side of this Figure calculates the Median-Mean Difference using the aggregated results of Michigan's 2006-2010 statewide elections, while the right side of the Figure uses the aggregated results of the 2012-2016 statewide elections. In both diagrams, the horizontal axis depicts the Median-Mean Difference of each plan, while the vertical axis depicts the Reock score of each plan, measuring the plan's geographic compactness. In each diagram, the red star represents the enacted House plan, while the gray circles represent the 1,000 computer-simulated plans.

Using either set of elections, it is very clear that the enacted House plan is significantly more skewed in favor of Republicans than every single one of the 1,000 computer-simulated plans. Almost all of the computer-simulated plans have a Median-Mean Difference between 2.9% to 4.5%, using the 2006-2010 statewide elections, and between 4.5% to 6.0%, using the 2012-2016 statewide elections. Not a single simulated plan comes even close to the enacted plan's extreme Median-Mean Difference of 5.19%, using the 2006-2010 statewide elections, and 6.86%, using the 2012-2016 statewide elections. I thus conclude, with extremely strong statistical certainty, that the enacted House plan's extreme Median-Mean Difference is clearly not the result of Michigan's natural political geography, combined with the application of Michigan's statutory redistricting guidelines. It is a partisan outlier driven by partisan intent.

Figure 17:


Comparison of 1,000 Computer−Simulated House Plans
to the Enacted Congressional Plan on Median−Mean Difference
Legend:
1,000 Computer−Simulated House Districting Maps
Enacted House Plan (2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.44
0.43
0.42
0.41
Enacted Plan
(2011)
0.03
0.035
0.04
0.045
0.05
0.055
Median−Mean Difference:
(Median District Minus Mean District Republican Vote Share,
Calculated Using All 2006−2010 Statewide Elections)

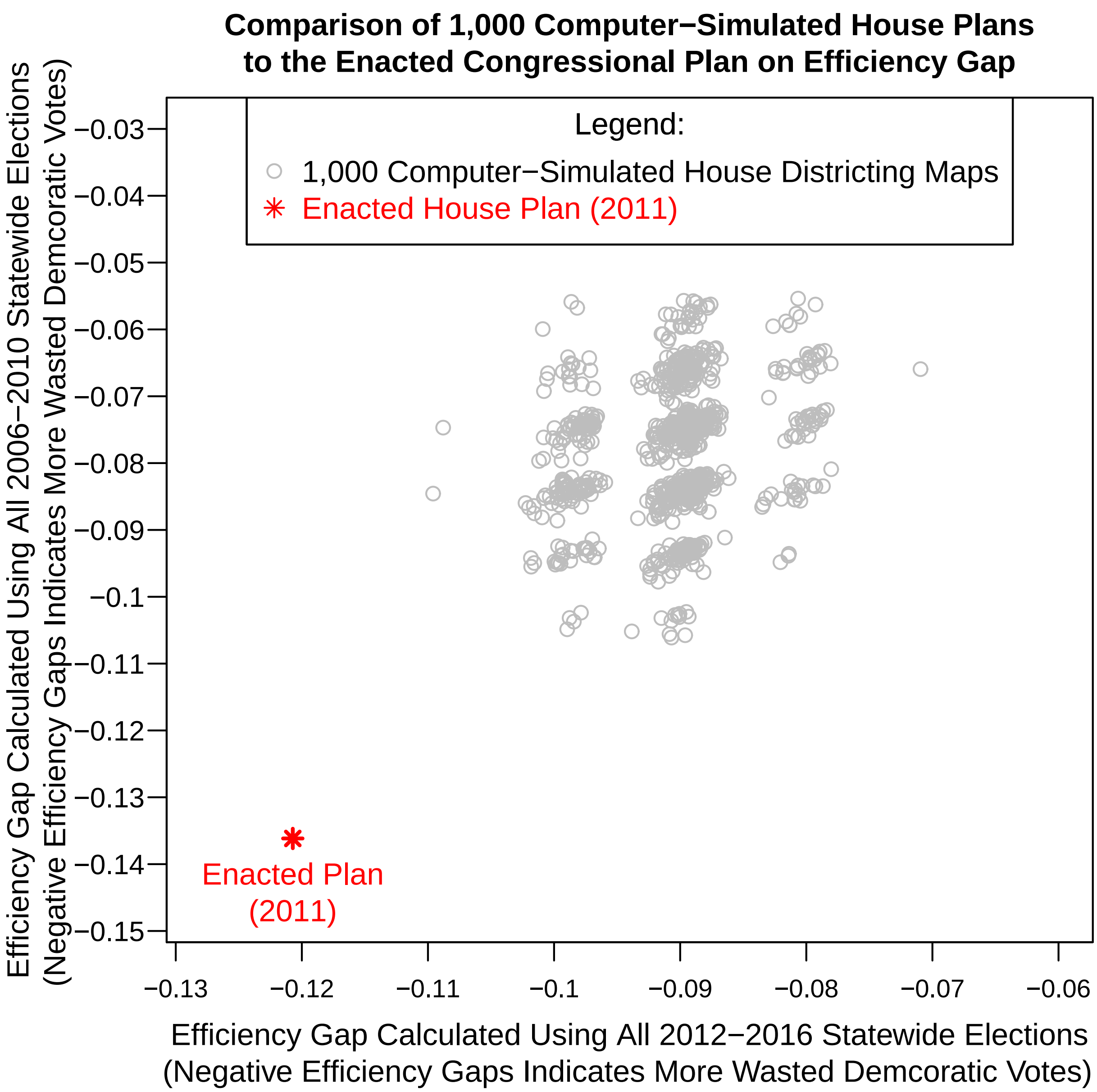

Comparison of 1,000 Computer−Simulated House Plans
to the Enacted Congressional Plan on Median−Mean Difference
Legend:
1,000 Computer−Simulated House Districting Maps
Enacted House Plan (2011)
Mean Reock Score of Districting Plan
(Higher Reock Score Indicates Greater Compactness)
0.44
0.43
0.42
0.41
Enacted Plan
(2011)
0.04
0.045
0.05
0.055
0.06
0.065
0.07
Median−Mean Difference:
(Median District Minus Mean District Republican Vote Share,
Calculated Using All 2012−2016 Statewide Elections)

The fact that the 1,000 simulated plans in Figure 17 all produce a small but positive Median-Mean Difference results, at least in part, from the fact that, as noted earlier, the simulation algorithm simply freezes 12 House Districts (covering Detroit, Dearborn, and Southfield) from the enacted plan, without attempting to draw these districts' boundaries in a partisan-neutral manner. The small Median-Mean Differences in the computer-simulated plans may also partially reflect a modest skew in Michigan's voter geography that slightly benefits the Republicans in districting. This modest skew in the simulated districting plans may result naturally from Democratic voters' tendency to cluster in urban areas of Michigan, as I have explained in my previous academic research.[8] But more importantly, even when combined with the skew from freezing majority-minority districts, the range of this natural skew, as shown in Figure 17, is always much smaller than the extreme 6.86% Median-Mean Difference (calculated using the 2012-2016 statewide elections) observed in the enacted House plan. Hence, these results confirm the main finding that the enacted plan creates a partisan outcome that cannot be explained by Michigan's voter geography or by the application of the MCL § 4.261 redistricting guidelines. Instead, the extremity of the enacted plan's Median-Mean Difference can only be explained by a districting process that pursued a partisan goal.

Next, I compare the enacted House plan to the 1,000 computer-simulated House plans using the efficiency gap. Figure 18 illustrates these efficiency gap calculations: The vertical axis depicts each plan's efficiency gap using the 2006-2010 statewide elections, while the horizontal axis depicts each plan's efficiency gap using the 2012-2016 statewide elections. The 1,000 gray circles in this Figure represent the computer-simulated districting plan, while the red star represents the enacted House plan.

[8] Jowei Chen and Jonathan Rodden, 2013. "Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures" *Quarterly Journal of Political Science*, 8(3): 239-269; Jowei Chen and David Cottrell, 2016. "Evaluating Partisan Gains from Congressional Gerrymandering: Using Computer Simulations to Estimate the Effect of Gerrymandering in the U.S. House." *Electoral Studies*, Vol. 44, No. 4: 329-430.

Figure 18:


Comparison of 1,000 Computer−Simulated House Plans
to the Enacted Congressional Plan on Efficiency Gap
Legend:
1,000 Computer−Simulated House Districting Maps
Enacted House Plan (2011)
Enacted Plan
(2011)
Efficiency Gap Calculated Using All 2006−2010 Statewide Elections
(Negative Efficiency Gaps Indicates More Wasted Demcoratic Votes)
−0.03
−0.04
−0.05
−0.06
−0.07
−0.08
−0.09
−0.1
−0.11
−0.12
−0.13
−0.14
−0.15
−0.13
−0.12
−0.11
−0.1
−0.09
−0.08
−0.07
−0.06
Efficiency Gap Calculated Using All 2012−2016 Statewide Elections
(Negative Efficiency Gaps Indicates More Wasted Demcoratic Votes)

This Figure reveals that most of the 1,000 simulated districting plans reflect a small amount of electoral bias in favor of the Republicans. Nevertheless, not a single simulated plan exhibits an efficiency gap greater than 11%. These patterns illustrate that a non-partisan districting process very commonly produces a House plan in Michigan with a small amount of pro-Republican electoral bias, as measured by efficiency gap. To produce a map with significant electoral bias deviating by over 11% from a zero efficiency gap, however, would require more extraordinary and deliberate partisan map-drawing efforts.

However, Michigan's enacted House plan, denoted in Figure 18 as a red star, produces an efficiency gap that is extremely inconsistent with and outside of the entire range of the 1,000 computer-simulated plans. The enacted plan creates an efficiency gap of -13.6% using the 2006-2010 statewide elections and -12.1% using the 2012-2016 statewide elections, indicating that the plan consistently results in significantly more wasted Democratic votes than wasted Republican votes. Thus, the level of electoral bias in the enacted House plan is not only entirely outside of the range produced by the simulated plans, the enacted plan's efficiency gap is far more biased than even the most biased of the 1,000 simulated plans. The improbable nature of the enacted House plan's efficiency gap allows us to conclude with overwhelmingly high statistical certainty that non-partisan districting criteria mandated in MCL § 4.261, combined with Michigan's natural political geography, could not have produced a districting plan as electorally skewed as the enacted House plan. The plan is a partisan outlier created with partisan intent.

The Partisan Durability of Michigan's Enacted Districting Plans

Having found that Michigan's enacted Congressional, Senate, and House plans are partisan outliers compared to computer-simulated plans produced by following Michigan's statutory redistricting criteria, I then analyzed whether these enacted plans are politically durable. The partisan durability of a districting plan refers to whether a plan would allow a particular political party to preserve its majority control over a chamber or congressional delegation under a reasonable range of alternative electoral conditions. In other words, would the Republicans still likely win a majority of Michigan's congressional districts even during an election in which overall Republican electoral performance is worse than normal?

For decades, political scientists have used uniform swing analysis to assess the durability of any given electoral system. [9] Uniform swing analysis begins with the general observation that when a political party performs worse than normal in a given election, its vote share generally decreases by a comparable degree in all legislative districts across Michigan; a party's poor electoral performance is usually not limited to a single district. Similarly, when a party has a better than normal year at the polls, its vote share generally rises in all districts across Michigan, not just a single district.

Hence, to assess how a party would perform under alternative electoral conditions, political scientists conduct a uniform swing analysis, simulating a uniform increase (or decrease) in a party's vote share across all districts within a state. One can then assess, for example, how many congressional districts Republicans would still win if the party suffered a uniform -1% swing to its vote share in every district within Michigan.

Hence, a uniform swing analysis can determine whether a party's majority control over a legislative chamber or congressional delegation is strong enough to withstand a reasonable range of alternative electoral conditions. If a districting plan gives Republicans control over a majority of all districts, and only a significant pro-Democratic uniform swing would allow Democrats to ever win a majority of districts in a single election, then the Republicans' majority control over the districts is a durable one. Hence, partisan durability simply describes whether a party's

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[9] Andrew Gelman and Gary King, "A unified method of evaluating electoral systems and redistricting plans." American Journal of Political Science, 38 (1994), pp. 514-554. D. Butler, D. Stokes. Political Change in Britain: Forces Shaping Electoral Choice. Macmillan, London (1969).

control over a majority of districts is generally safe under a reasonable range of alternative electoral conditions.

To assess the partisan durability of Michigan's enacted plans, I evaluate the actual results of each set of Congressional (2012, 2014, and 2016), Senate (2014), and House (2012, 2014, and 2016) elections held using the enacted plans. All seven of these sets of elections resulted in Republicans winning a majority of Michigan's districts. Hence, for each set of elections, I calculate the smallest pro-Democratic uniform swing that would have been necessary in order for Democrats to win one-half of all districts - that is, how much of a uniform swing would have been necessary for Republicans to lose their majority control over Michigan's districts?

Table 5 presents these uniform swing calculations. For example, in November 2012, Republicans won 9 of 14 congressional districts, and the Republican vote share in the seventh-most Democratic district was 53.37%. Therefore, a uniform swing of -3.37% would have been needed for Republicans to lose their majority control over districts and for Democrats to win exactly 7 out of 14 districts. This uniform swing calculation indicates that Republicans possessed durable majority control over Michigan's congressional districts, and this majority control could withstand normal electoral fluctuations. Figure C1 in Appendix C illustrates the district-by-district breakdown of this uniform swing analysis.

A similar conclusion emerges from uniform swing analyses of each of the other six legislative and congressional elections. In the 2014 and 2016 congressional elections, Republicans won 9 of 14 congressional districts, and a uniform swing of -6.45% (in November 2014) and -7.79% (in November 2016) would have been required for Democrats to win one-half of all districts. In the November 2014 Senate elections, Republicans won 27 of 38 districts, and a uniform swing of -6.4% would have been required for Democrats to win one-half (19 of 38) of all districts. Finally, Republicans won 59, 63, and 63 of Michigan's 110 House Districts in the 2012, 2014, and 2016 elections, respectively. A pro-Democratic uniform swing of -1.04% (in November 2012), -2.25% (in November 2014), and -4.14% (in November 2016) would have been required for Democrats to win one-half (55 of 110) of all House districts. Together, these results demonstrate that not only did Republicans win a majority of all districts in each of these seven sets of elections, but this Republican majority control would also have been durable even under a reasonable range of alternative electoral conditions.

Table 5 describes all of these uniform swing calculations using the actual election results of the Congressional, State Senate, and State House elections held during 2012-2016, and in Appendix C, Figures C1 through C7 illustrate the district-by-district breakdowns of these uniform swing calculations.

Single-District Comparisons of Enacted Plan and Simulated Plan Districts

Appendix D presents single-district comparisons of the enacted plan and the computer-simulated plans for Michigan's Congressional delegation, State Senate, and State House. I compare the partisanship of single districts from the enacted plan and the computer-simulated plans in order to identify the specific districts that were 'cracked' and 'packed', thus explaining why each of the enacted plans were partisan outliers when compared to the computer-simulated plans created using the partisan-neutral statutory redistricting guidelines.

In the single-district comparisons that appear in Appendix D, I compare districts from the enacted and the computer-simulated plans in two ways: First, I align the districts from each enacted and computer-simulated plan from least to most Republican. I then directly compare, for example, the partisanship of the most Republican Congressional district from the enacted plan to the partisanship of the most Republican district from each of the 1,000 simulated Congressional plans. I then compare the second-most Republican enacted district to the second-most Republican district from each of the 1,000 simulated Congressional plans. And so on.

A second method of comparison presented in Appendix D is based on district geography. I directly compare each enacted district to the district from each computer-simulated plan that geographically overlaps the most with the enacted district. These comparisons allow me to identify partisan differences between the enacted and the simulated plans in terms of how each region of Michigan was districted.

In general, whenever an enacted district is a partisan outlier compared to the simulated districts that cover the same geographic area, I can infer that the enacted plan's boundaries in this area were manipulated in a manner inconsistent with Michigan's statutory redistricting guidelines. When viewed in the broader context of the entire plan, these single-district comparisons reveal the precise districts that were 'cracked' or 'packed,' thus allowing the enacted plan to create an outlying partisan outcome compared to the computer-simulated plans.

For example, Figures D1 through D3 allow me to identify the precise districts within the enacted Congressional plan that were "cracked" or "packed". These figures compare the partisanship of each enacted Congressional district to the partisanship of the computer-simulated districts that cover the same geographic area. These comparisons thus allow me to identify, for example, what the partisanship of Kalamazoo's congressional district would have been if districts in southwest Michigan had been drawn according to the statutory redistricting guidelines.

These figures reveal, for example, that Congressional District 5 (Saginaw, Flint, and Bay City) had the effect of packing together Democrats to an unnatural degree, creating a 62% Democratic district. Not a single computer-simulated congressional district covering this general area of Saginaw, Flint, and Bay City would have packed together Democrats so heavily. Every computer-simulated congressional district in this region would have been between 50-60% Democratic. The figures also show that Congressional Districts 9 and 12 were similarly packed with Democratic voters.

On the other hand, the figures reveal that Congressional Districts 4, 7, 8, and 10 had the effect of 'cracking' Democratic voters, thus resulting in safer Republican majorities in each of these four districts. For each of these four enacted districts, the figures reveal that computer-simulated districts covering the same area would have created either a more partisan-competitive district or perhaps even a slightly Democratic-leaning district. But in the enacted plan, these four enacted districts were made safer for Republicans by removing Democratic voters and concentrating them in the 'packed' districts identified above.

Similarly, Figures D4 through D7 present single-district comparisons of the enacted Senate plan to the computer-simulated Senate plans. Figures D8 through D16 present single-district comparisons of the enacted House plan to the computer-simulated House plans.

For the enacted Congressional, Senate, and House plans, I determine whether each enacted district is a partisan outlier compared to the simulated districts that overlap geographically with the enacted district. Specifically, when determining whether a district is a partisan outlier, I use the district's Republican vote share across all 2012-2016 statewide elections to measure the district's partisanship, as described earlier in this report. I calculate whether the enacted district's partisanship is outside of the middle 95% range of the simulated geographically overlapping districts. I consider only geographically overlapping simulated

districts that overlap with at least 50% of the total population of the enacted district. Using this method, I identify the following districts as partisan outliers:

In the enacted Congressional plan, Congressional Districts 1, 4, 5, 8, 9, 10, 11, and 12 are partisan outliers when compared to their respective computer-simulated geographically overlapping districts.

In the enacted Senate plan, Senate Districts 8, 9, 18, 22, 24, 27, and 32 are partisan outliers when compared to their respective computer-simulated geographically overlapping districts.

In the enacted House plan, House Districts 11, 12, 14, 16, 19, 20, 21, 30, 31, 32, 36, 43, 44, 45, 51, 52, 53, 55, 57, 60, 62, 63, 65, 69, 75, 76, 80, 87, 91, 92, 94, 98, 103, 105, 106, and 107 are partisan outliers when compared to their respective computer-simulated geographically overlapping districts.

Absent some other explanation, this analysis strongly suggests that these outlier districts listed above are the most effectively cracked and packed districts in the enacted maps. In addition, when an enacted district has zero computer-simulated districts that overlap with 50% of enacted district's population, such a finding indicates that the enacted district was drawn in a manner that did not follow Michigan's statutory redistricting guidelines.

Table 5:
Share of Districts and Share of Statewide Vote Won by Republican Candidates In the 2002-2016 Congressional, House, and Senate Elections.

	Congressional Elections, 2012-2016			
Election Year	Republican Vote Share in the 7th-Most Democratic Congressional District:	Size of Uniform Swing Necessary for Democrats to Win One-Half (7 of 14) of Congressional Districts:	Statewide Republican Vote Share in Congressional Elections	Statewide Republican Vote Share After Applying Uniform Swing (From 2nd Column):
Nov. 2012	53.37%	-3.37%	47.60%	44.23%
Nov. 2014	56.45%	-6.45%	49.11%	42.66%
Nov. 2016	57.81%	-7.81%	50.55%	42.74%

	State Senate Elections, 2014			
Election Year	Republican Vote Share in the 19th-Most Democratic Senate District:	Size of Uniform Swing Necessary for Democrats to Win One-Half (19 of 38) of Senate Districts:	Statewide Republican Vote Share in Senate Elections	Statewide Republican Vote Share After Applying Uniform Swing (From 2nd Column):
Nov. 2014	56.40%	-6.4%	50.73%	44.33%

	State House Elections, 2012-2016			
Election Year	Republican Vote Share in the 55th-Most Democratic House District:	Size of Uniform Swing Necessary for Democrats to Win One-Half (55 of 110) of House Districts:	Statewide Republican Vote Share in Congressional Elections	Statewide Republican Vote Share After Applying Uniform Swing (From 2nd Column):
Nov. 2012	51.04%	-1.04%	46.82%	45.78%
Nov. 2014	52.25%	-2.25%	48.78%	46.53%
Nov. 2016	54.01%	-4.01%	50.03%	46.02%

Executed this 1st day of June 2018.

Signed:

Jowei Chen

Appendix A:
Michigan's Statutory Redistricting Guidelines
And the Computer-Simulated Districting Algorithm

Michigan has two redistricting statutes - MCL § 4.261 et seq (Act 463 of 1996) and MCL § 3.63 et seq (Act 221 of 1999) – that describe in detail the criteria to be followed in the drawing of the state's Congressional, Senate, and House districts. The statutes describe five criteria to be followed in producing each districting plan: 1) Contiguity; 2) Equal population thresholds; 3) Minimizing county breaks; 4) Minimizing municipal breaks; and 5) Geographic compactness. Furthermore, the statutes even establish a hierarchy specifying which criteria are to be prioritized over others when drawing districts: Both statutes are clear that district contiguity is an absolutely inviolable principle and that county and municipal lines may be broken only for the purpose of satisfying the district population threshold requirements. This statutory hierarchy thus establishes a clear order of priority for the five districting criteria. For example, a districting plan may not create additional county or municipal breaks for the sake of improving district compactness; nor may a plan deviate from the district population thresholds for the sake of avoiding a county or municipal break.

Furthermore, both statutes state that the list of districting guidelines detailed in each statute is exhaustive. MCL § 4.261 mandates that House and Senate plans "shall be enacted using only the following guidelines," while MCL § 3.63 similarly requires that the drawing of Congressional plans must follow "only these guidelines in the following order of priority." Hence, it is clear that both statutes not only specify the five districting criteria and their order of priority, but they also prohibit any other considerations, such as the partisan composition of districts or the protection of incumbents.

Because of the clarity, specificity, and exhaustiveness of MCL § 4.261 and MCL § 3.63 regarding the five districting criteria, as well as their order of priority, programming the districting simulation algorithm to produce Congressional, Senate, and House plans for Michigan was a purely technical exercise, with no subjective judgment or guesswork needed. I simply followed the criteria detailed by the two redistricting statutes and instructed the computer algorithm to adhere strictly to these criteria, with no other considerations permitted.

The simulation algorithm proceeds as follows: First, the algorithm begins with a set of base geographies to be used as building blocks for constructing a simulated plan. In creating State House plans, I use Voting Tabulation District (VTD) boundaries as the building blocks. In

creating State Senate and Congressional plans, I use municipal (MCD) boundaries as the building blocks for simulated plans. Second, the algorithm randomly divides up these geographies into the appropriate number of contiguous districts (eg, 38 State Senate districts), each of roughly equal population; at this point, these districts are unlikely to be of perfectly equal population. Third, the algorithm then considers each of 10 million randomly-proposed, iterative changes to the various boundaries between the districts. Each of these proposed iterative changes is randomly generated, with no partisan or racial considerations considered. Each proposed iterative change is accepted only if the resulting districts 1) Would be within the 5% population deviation threshold statutorily mandated for Senate and House districting plans; 2) Would not increase the number of county breaks across the entire plan; and 3) Would not increase the number of municipal breaks across the entire plan. By considering and selectively implementing a large number of random iterative changes to the districts' boundaries, the algorithm thus gradually decreases the number of county and municipal breaks in the plan. These iterative changes result in a plan in which county and municipal breaks occur only when absolutely necessary to comply with the equal population and contiguity mandates of Michigan's redistricting guidelines.

In simulating Congressional plans, the algorithm contains one additional step not used when simulating Senate and House plans: Unlike State House and Senate districts, Congressional districts are required to contain perfectly equal populations. Thus, after the aforementioned steps, the algorithm randomly selects municipalities to be broken only when necessary for equalizing the populations of all Congressional districts. The algorithm considers a large number of possible breaks of the municipality, and the possible break that maximizes district compactness is selected. This final step results in Congressional districts that contain a population of either 705,974 or 705,975, while otherwise minimizing county and municipal breaks and preserving district contiguity.

Below, I describe in detail these five districting criteria in order of priority and explain how each criterion is implemented by the computer algorithm in producing simulated plans for Michigan's Congressional, Senate, and House districts:

1) *District Contiguity:* Michigan statute requires Congressional, Senate, and House districts to be "contiguous by land," while specifying that contiguity cannot be achieved through "areas that meet only at points of adjoining corners" (MCL 3.63(i) and MCL 4.261(c)).

Therefore, the computer simulation algorithm I use for this report requires districts to be contiguous by land, with no point contiguity. In other words, a district that combines two areas is considered contiguous only if those two areas share common border of non-zero length. For example, a district consisting only of West Bloomfield Township and Southfield Township is not considered contiguous because the two townships meet only at a single point and thus do not share a common border of non-zero length. On the other hand, a district consisting of West Bloomfield Township and White Lake Township is considered contiguous because these two townships share a very short common border of non-zero length at the southern end of Williams Lake Road.

The simulation algorithm also considers the Mackinac Bridge, which connects Michigan's Lower and Upper Peninsulas, to be land for the purposes of determining district contiguity. Census Bureau maps of Michigan do not recognize the Mackinac Bridge as land. Thus, the Lower and Upper Peninsulas are not connected by any Census Bureau-recognized land mass. However, it would be mathematically impossible to avoid drawing districts that cross the Mackinac Bridge while simultaneously complying with the Michigan statutory requirements regarding population equality. If the Mackinac Bridge were not treated as land, then any district that includes portions of both Peninsulas, including Congressional District 1, Senate District 37, and House District 107 of Michigan's current enacted plans, would violate the land contiguity requirement.

The simulation algorithm thus allows the Lower and Upper Peninsulas to be connected in ways similar to how the enacted plans connect the Peninsulas. Specifically, a district that connects Mackinac County (Upper Peninsula) with either Wawatam Township or Mackinaw Township (Lower Peninsula) is considered to be contiguous, even though the contiguity of such a district is obviously achieved only via the Mackinac Bridge.

2) *Population Equality:* Michigan's 2010 Census population was 9,883,640, so Michigan statute requires the state's Congressional, Senate, and House plans to meet the following thresholds for population equality:

Each of Michigan's 14 Congressional districts has an ideal district population of 705,974.3. MCL 3.63 requires "precise mathematical equality of population" for congressional districts, meaning that each district's deviation from the ideal district population must be less than 1 person. Hence, the computer simulation algorithm requires that simulated congressional

plans are populated such that exactly ten districts have a population of 705,974, while the remaining four districts have a population of 705,975.

Each of Michigan's 38 State Senate districts has an ideal district population of 260,095.8. MCL 4.261(d) requires district populations to fall between 95% to 105% of the ideal district population, meaning that each Senate district must have a population no smaller than 247,091 and no greater than 273,100. Hence, the computer simulation algorithm requires that each of the 38 districts in each computer-simulated Senate plan has a population within this range.

Each of Michigan's 110 State House districts has an ideal district population of 89,851.27. MCL 4.261(d) requires district populations to fall between 95% to 105% of the ideal district population, meaning that each House district must have a population no smaller than 85,359 and no greater than 94,343. Hence, the algorithm requires that each of the 110 districts in each computer-simulated House plan has a population within this range.

A special population requirement for State House and Senate districts is outlined by MCL 4.261(i), which states that when a city is populous enough to contain multiple Senate or House districts, then district lines must be drawn to achieve "a population range of 98% to 102% of absolute equality between districts within that city." This special requirement applies to House and Senate districts within Detroit, as well as House districts within Grand Rapids.

To illustrate how this special population requirement is applied by the computer simulation algorithm, consider Grand Rapids, which has a population of 188,040. In any House districting plan that seeks to respect the city boundaries of Grand Rapids, the city will be divided into exactly two full House districts. As defined by MCL 4.261(i), "absolute equality between districts" within Grand Rapids would mean both districts having populations of precisely 94,020. Thus, the MCL 2.61(i) requirement of "a population range of 98% to 102% of absolute equality" means that the two House districts within Grand Rapids must have a population between 92,140 and 95,900. However, as explained earlier, MCL 4.261(d) also requires House districts to not exceed 105% of the "ideal district size" for House districts, thus prohibiting any State House district with a population larger than 94,343. Therefore, the computer simulation algorithm collectively applies both of these statutory requirements by requiring that the two House districts within Grand Rapids contain populations of no less than 92,140 and no greater than 94,343.

3) *Minimizing County Breaks:* After ensuring district contiguity and compliance with the population thresholds, the simulation algorithm then seeks to minimize the number of county

breaks in each simulated districting plan, using the definition of county breaks outlined in the previous section of this report. Michigan statutory law requires that districting plans minimize the total number of county breaks (e.g., "Congressional district lines shall break as few county boundaries as is reasonably possible," MCL § 3.63(c)(ii)). Therefore, the simulation algorithm allows county breaks to occur only when absolutely necessary to avoid non-contiguous districts or violating the equal population thresholds outlined above. The computer algorithm used in this report was thus able to produce simulated Congressional plans containing 10 county breaks, simulated Senate plans containing 5 county breaks, and simulated House plans containing 14 county breaks.

4) *Minimizing Municipal Breaks:* After ensuring district contiguity, compliance with the population thresholds, and the minimization of county breaks, the simulation algorithm then seeks to minimize the number of municipal breaks in each simulated districting plan, using the definition of municipal breaks outlined in the previous section of this report. Michigan statutory law requires that districting plans minimize the total number of municipal breaks (e.g., "Congressional district lines shall break as few city and township boundaries as is reasonably possible," MCL § 3.63(c)(iv)). Therefore, the simulation algorithm allows municipal breaks to occur only when absolutely necessary to avoid non-contiguous districts or violating the equal population thresholds outlined above. The algorithm seeks to minimize the total number of municipal breaks in any plan, with equal weight given to city and township breaks. The computer algorithm used in this report was thus able to produce simulated Congressional plans containing either 10 or 11 municipal breaks, simulated Senate plans containing zero municipal breaks, and simulated House plans containing either 13 or 14 municipal breaks.

5) *Geographic Compactness:* Both MCL § 3.63(c)(vii) and MCL § 4.261(j) specify compactness as one of the guidelines to be followed in the drawing of plans, but compactness is clearly lowest on the order of priority of the five criteria. Neither statute calls for compactness to take priority over any of the four aforementioned criteria.

Both statutes are extremely specific and technically detailed regarding how district compactness is to be precisely measured in the districts where compactness is required. The statutes do not use a common measure of compactness, such as Reock score. Instead, both statutes mandate that:

> Compactness shall be determined by circumscribing each district within a circle of minimum radius and measuring the area, not part of the Great Lakes and not part of another state, inside the circle but not inside the district (MCL § 3.63(c)(vii) and MCL § 4.261(j)).

The simulation algorithm thus seeks to achieve compactness where required only after prioritizing the four aforementioned criteria. Thus, after prioritizing district contiguity, equality of population, and the minimization of county and municipal breaks, the algorithm then favors districts that minimize the Michigan land area inside of each district's circumscribing circle but outside of the district itself.

In this report, I compare the relative compactness of the enacted plan and the computer-simulated plans using two quantitative measures: One measure simply sums up, across all districts in a particular plan, the total Michigan land area inside of each district's circumscribing circle but outside of the district itself; using this measure, a lower total area indicates greater geographic compactness. A second measure calculates, for all districts in a particular plan, the average ratio of each district's land area to the total land area inside the district's circumscribing circle; using this measure, a higher average ratio indicates greater geographic compactness.

I additionally evaluate the compactness of each enacted and simulated plan by calculating the average "Reock score" of the districts within each plan. The Reock score for each individual district is calculated as the ratio of the district's area to the area of the smallest bounding circle that can be drawn to completely contain the district. The Reock score for an entire plan is simply the average ratio for all the districts in the plan. Hence, the Reock measure of compactness is similar, though not identical, to the measure of compactness detailed in Michigan's two redistricting statutes. I report this measure for all plans because the Reock score is how political scientists and redistricting scholars commonly compare the relative compactness of various districting plans under consideration.

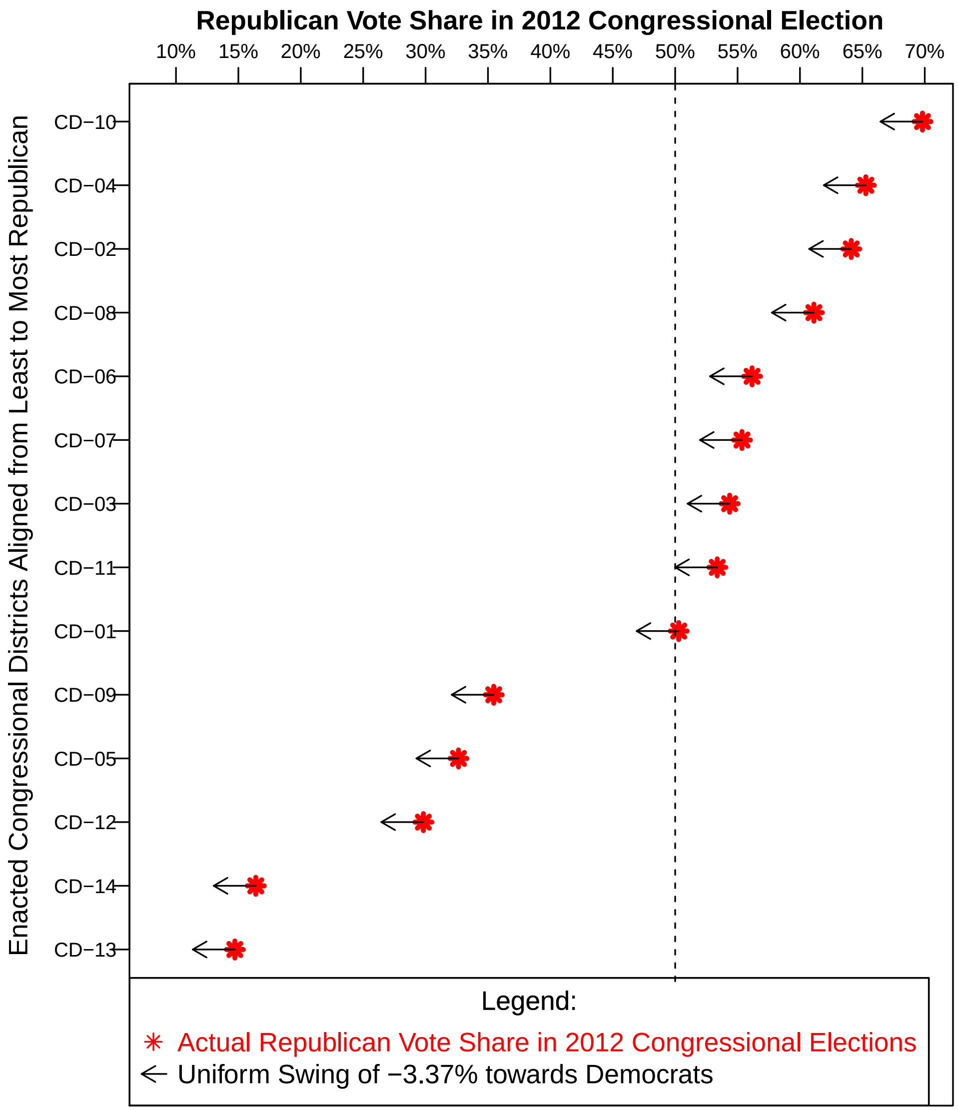
Appendix B:
Share of Districts and Share of Statewide Vote Won by Republican Candidates In the 2002-2016 Congressional, House, and Senate Elections.

Election Year	Statewide Republican Vote Share in Congressional Elections	Share of Congressional Districts Won by Republicans
2002	49.44%	60% (9 of 15)
2004	50.51%	60% (9 of 15)
2006	45.80%	60% (9 of 15)
2008	45.65%	46.7% (7 of 15)
2010	54.15%	60% (9 of 15)
2012	47.60%	64.3% (9 of 14)
2014	49.11%	64.3% (9 of 14)
2016	50.55%	64.3% (9 of 14)

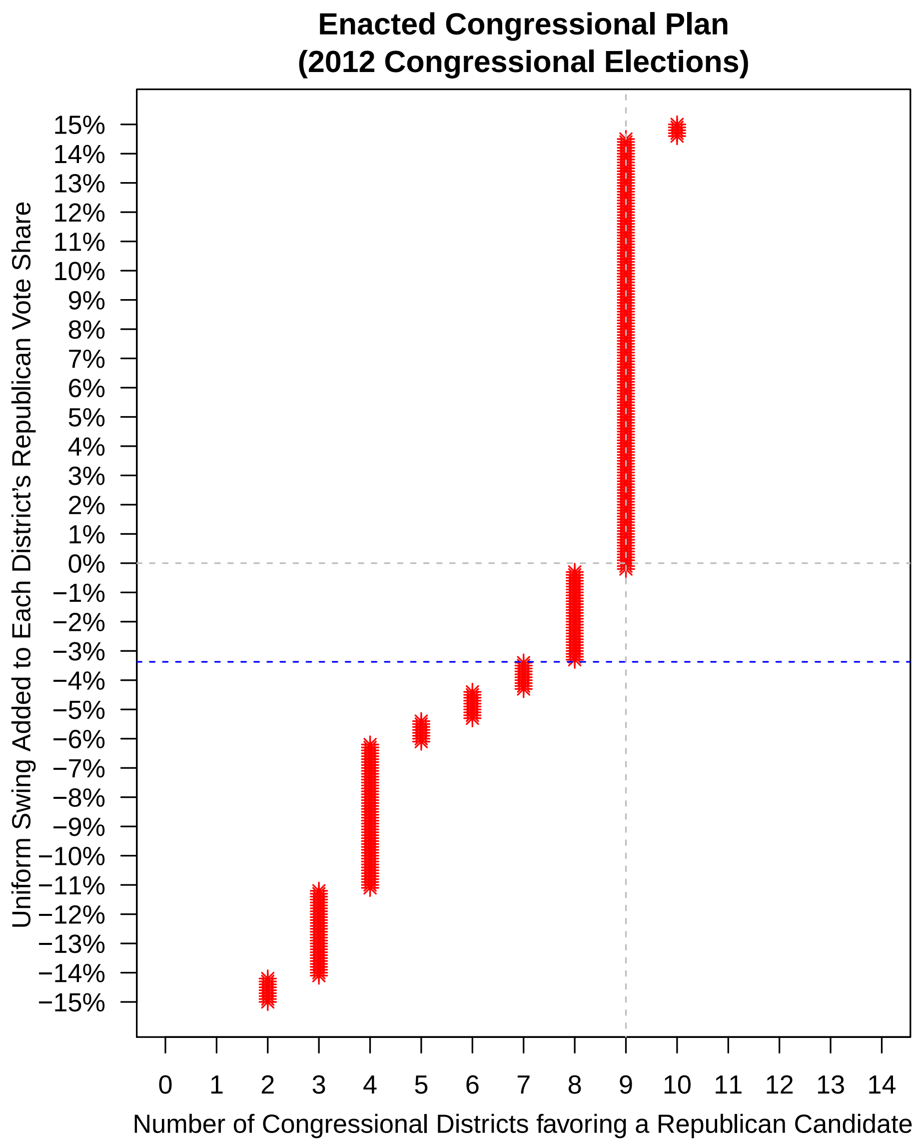
Election Year	Statewide Republican Vote Share in State Senate Elections	Share of State Senate Districts Won by Republicans
2002	50.42%	57.9% (22 of 38)
2006	45.58%	55.3% (21 of 38)
2010	54.48%	68.4% (26 of 38)
2014	50.73%	71.1% (27 of 38)

Election Year	Statewide Republican Vote Share in State House Elections	Share of State House Districts Won by Republicans
2002	50.48%	57.3% (63 of 110)
2004	48.59%	52.7% (58 of 110)
2006	45.11%	47.3% (52 of 110)
2008	42.25%	39.1% (43 of 110)
2010	53.86%	57.3% (63 of 110)
2012	46.82%	53.6% (59 of 110)
2014	48.78%	57.3% (63 of 110)
2016	50.03%	57.3% (63 of 110)

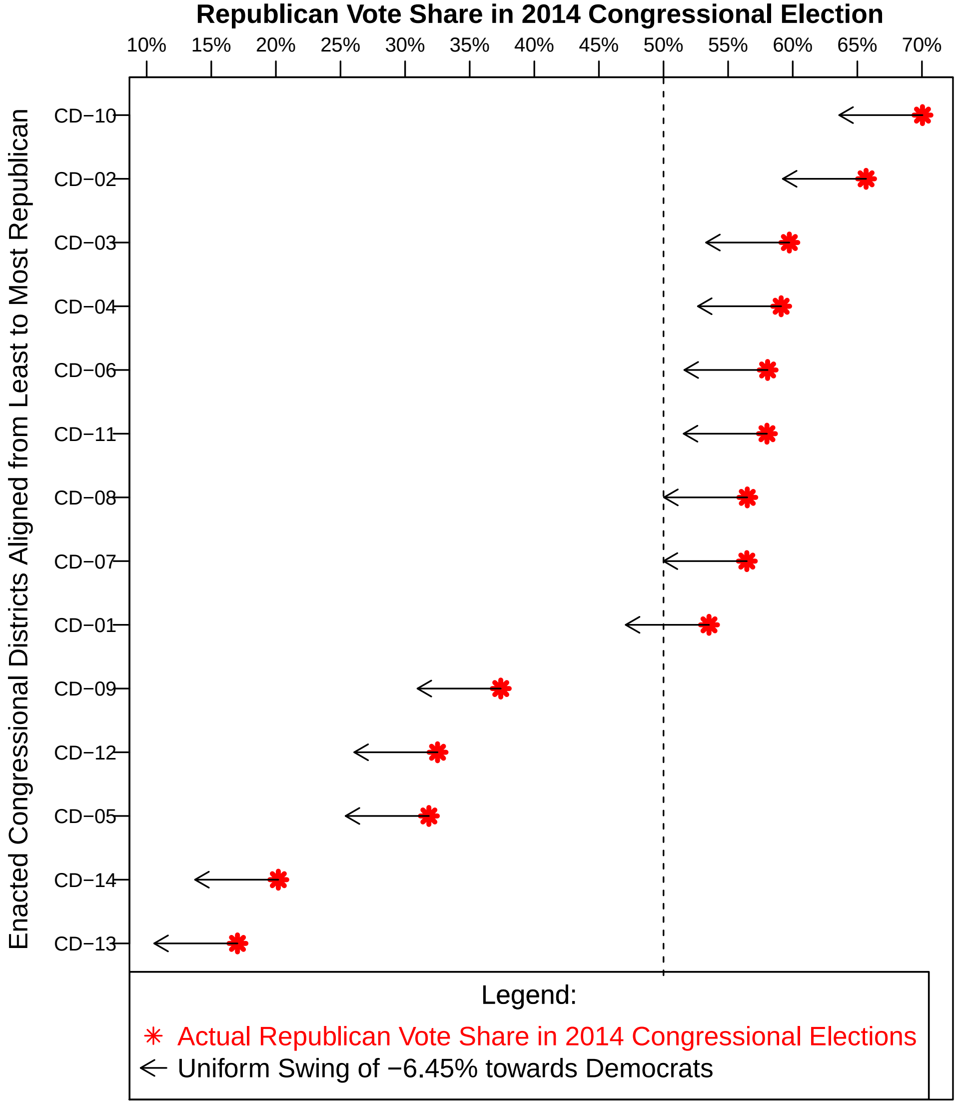
Appendix C, Figure C1:



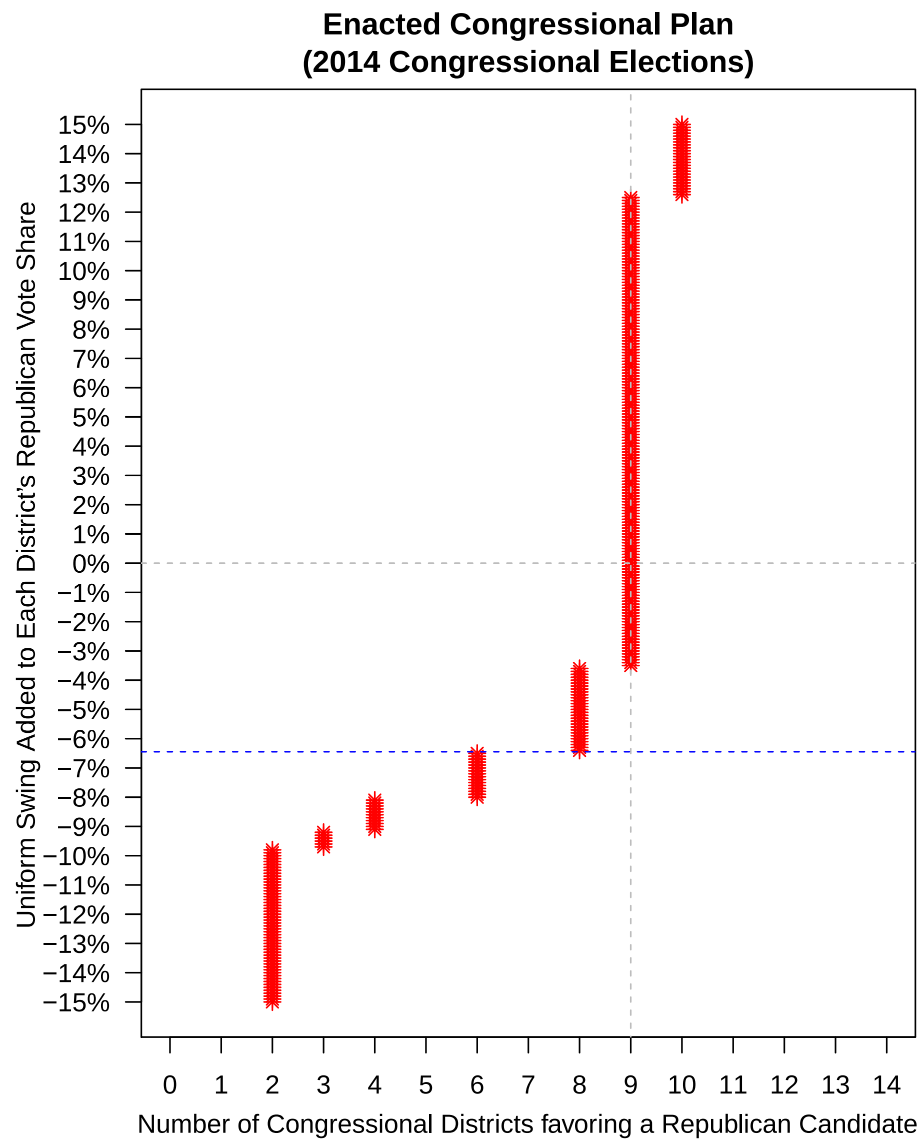
−3.37% = Size of Uniform Necessary for Democrats to Win
One−Half of Enacted Congressional Districts (7 of 14 seats)



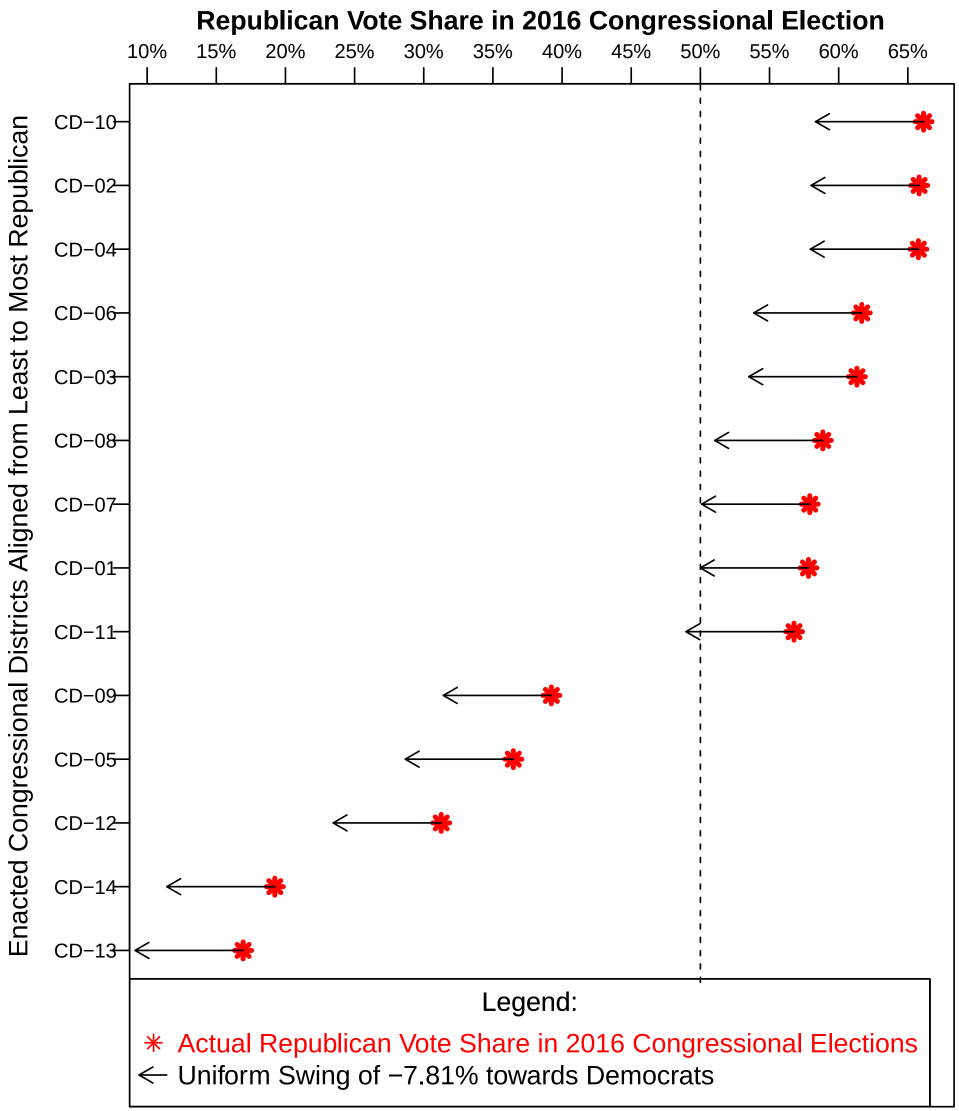
Appendix C, Figure C2:



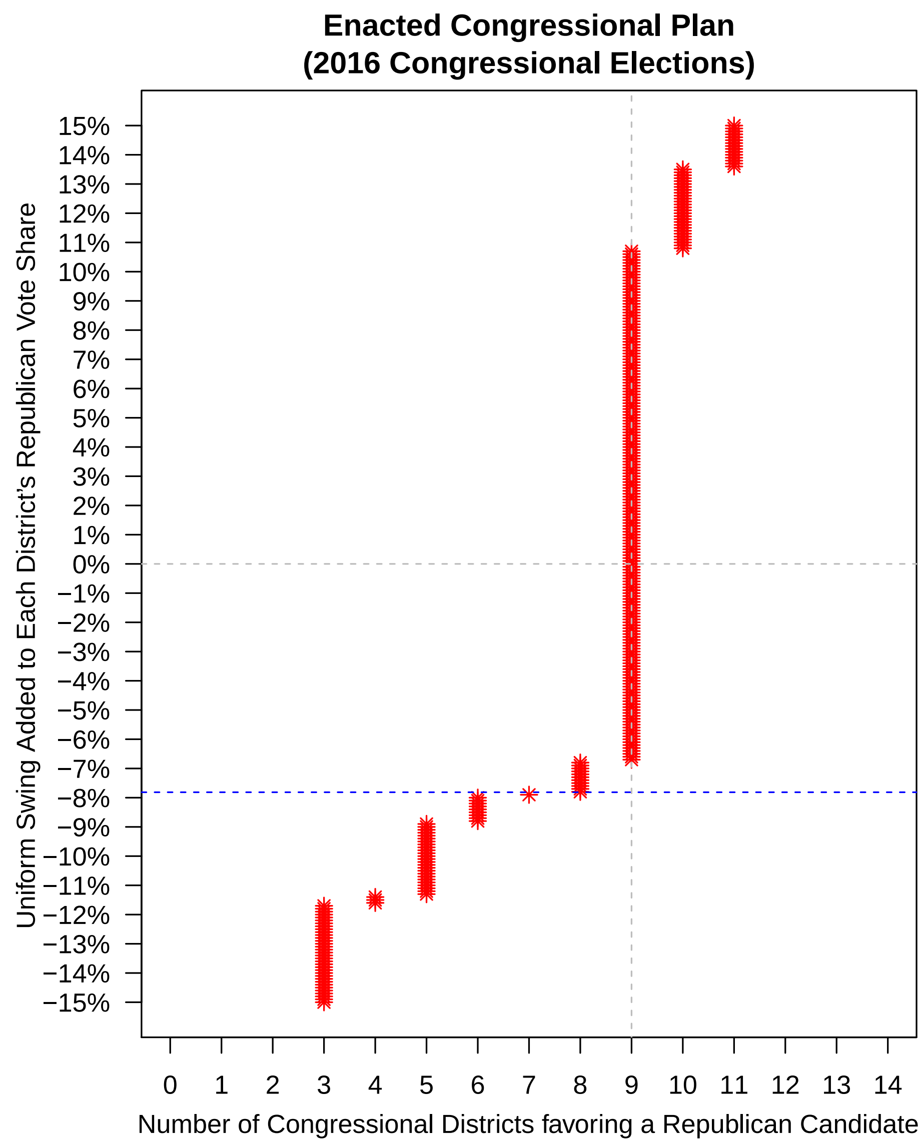
−6.45% = Size of Uniform Necessary for Democrats to Win
One−Half of Enacted Congressional Districts (7 of 14 seats)



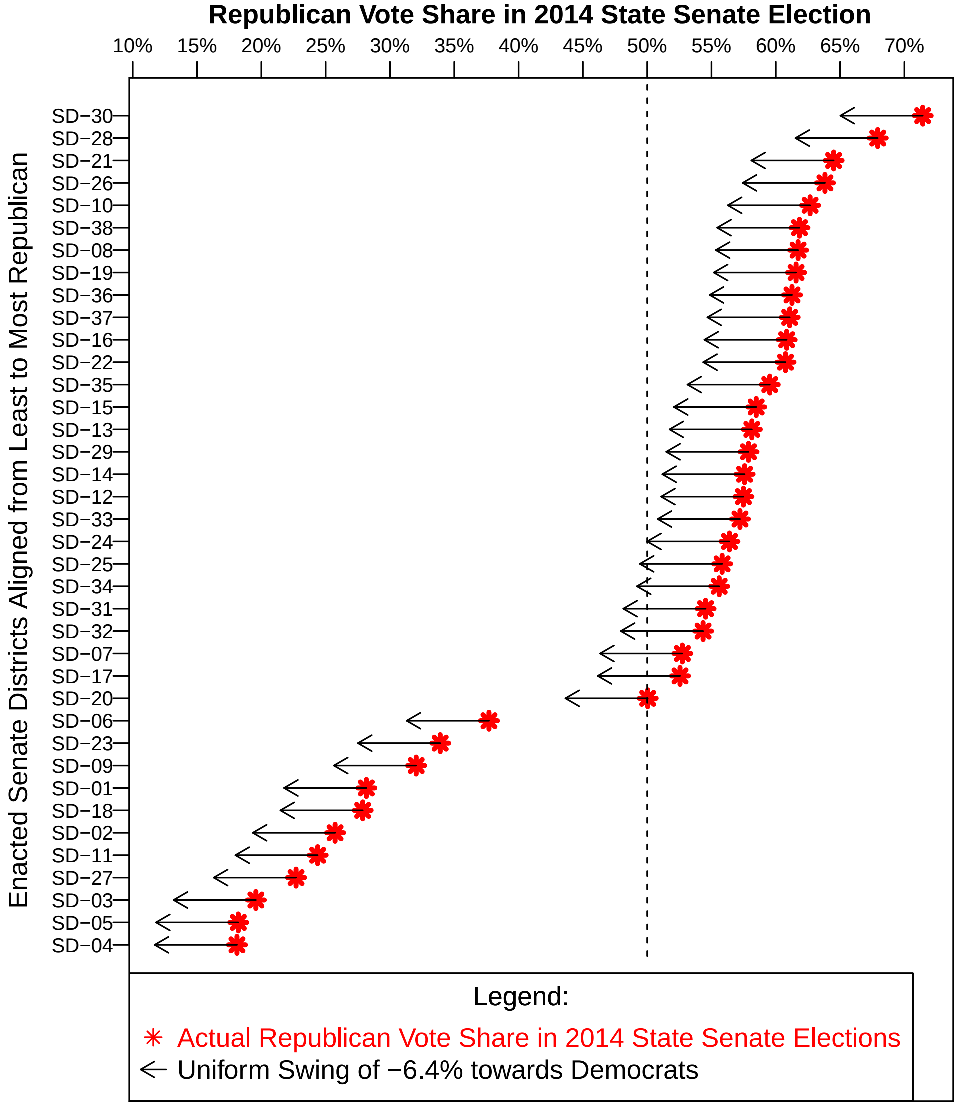
Appendix C, Figure C3:



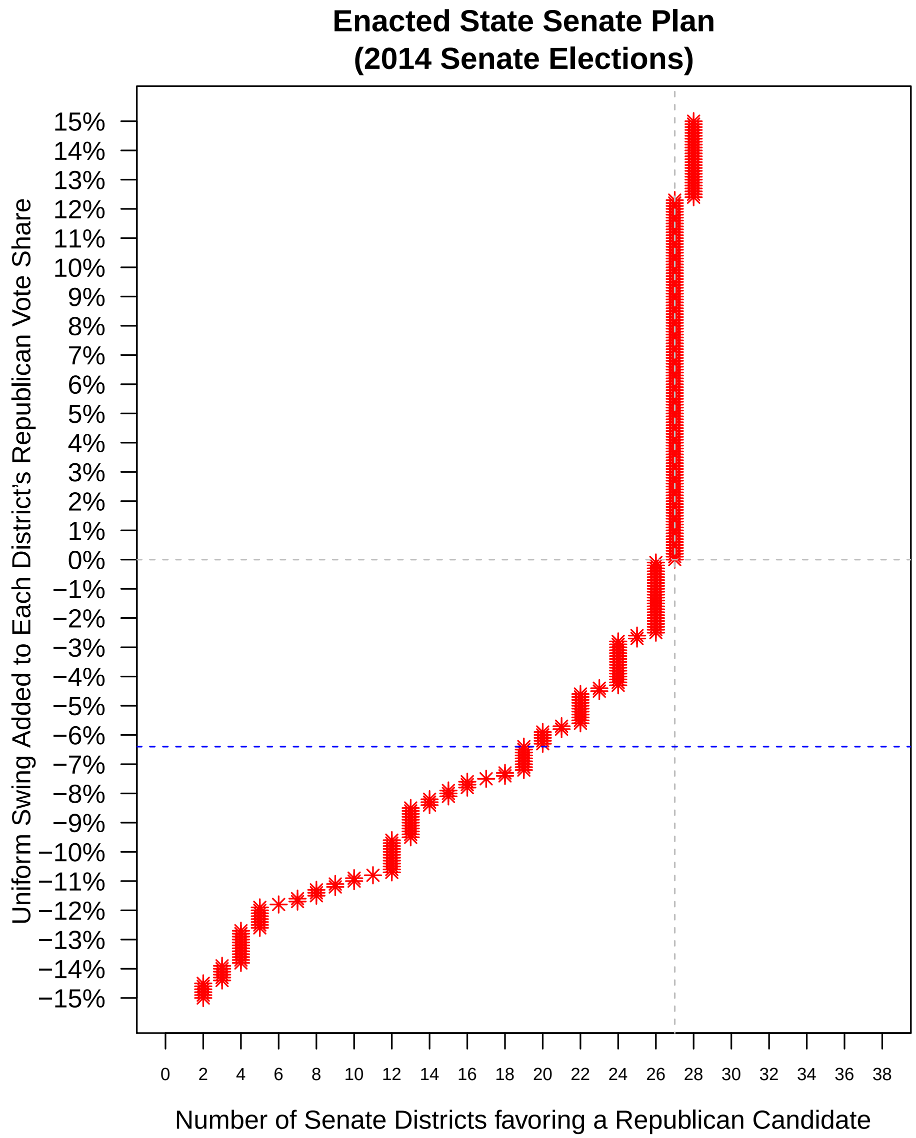
−7.81% = Size of Uniform Swing Necessary for Democrats to Win One−Half of Enacted Congressional Districts (7 of 14 seats)



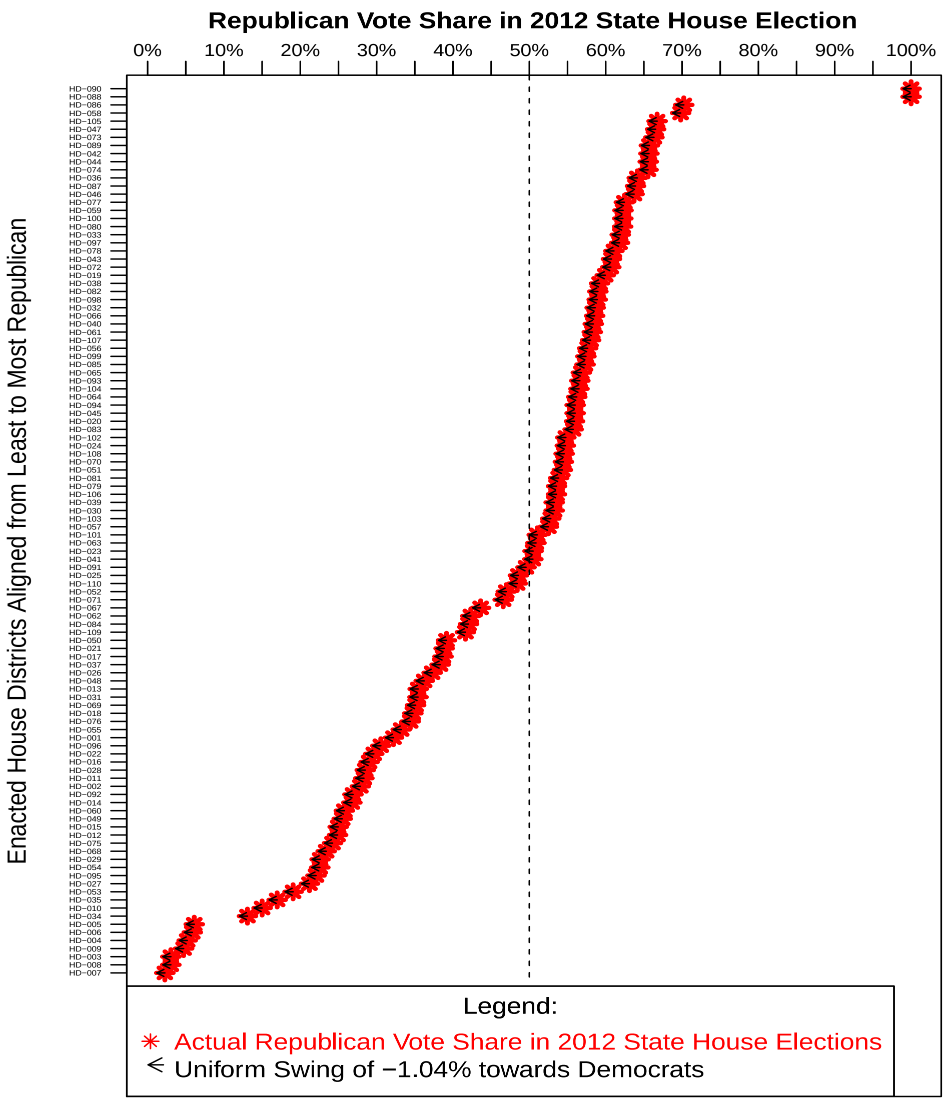
Appendix C, Figure C4:



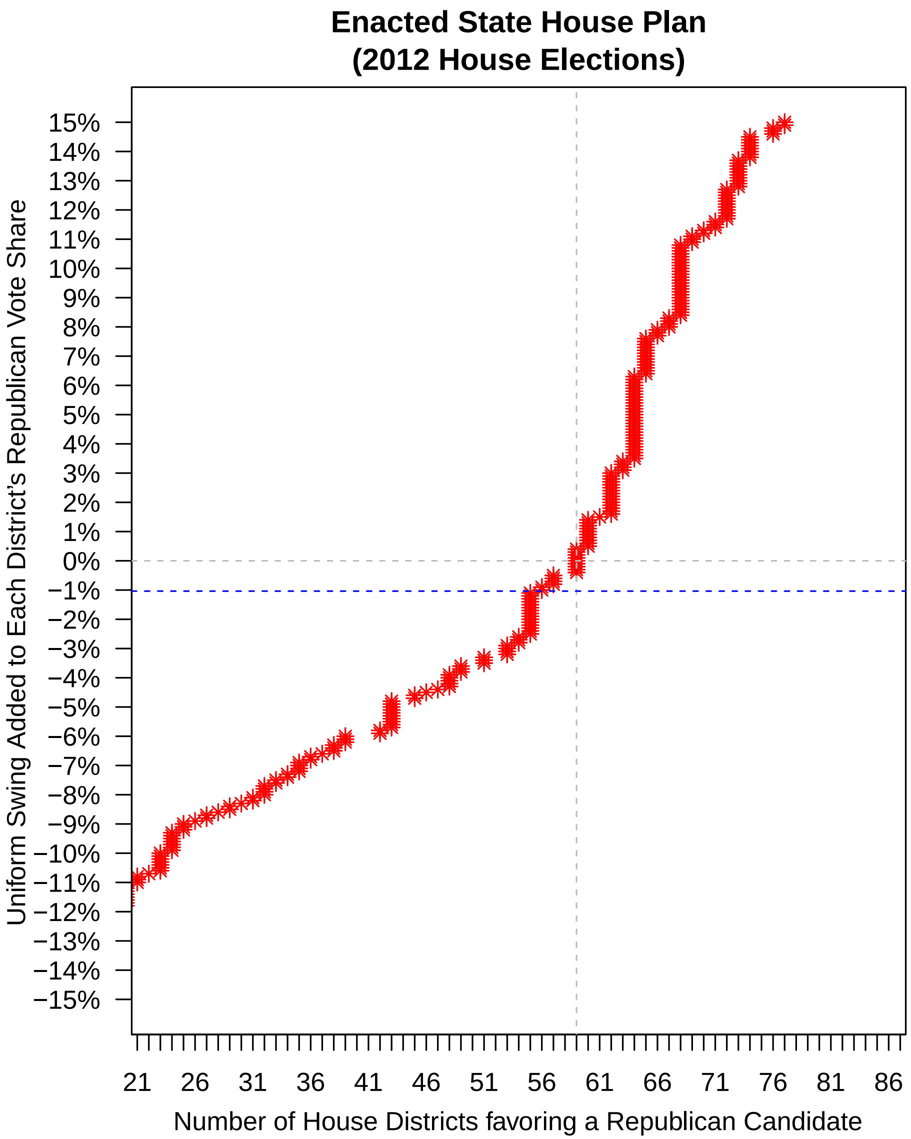
−6.4% = Size of Uniform Necessary for Democrats to Win
One−Half of Enacted Senate Districts (19 of 38 seats)



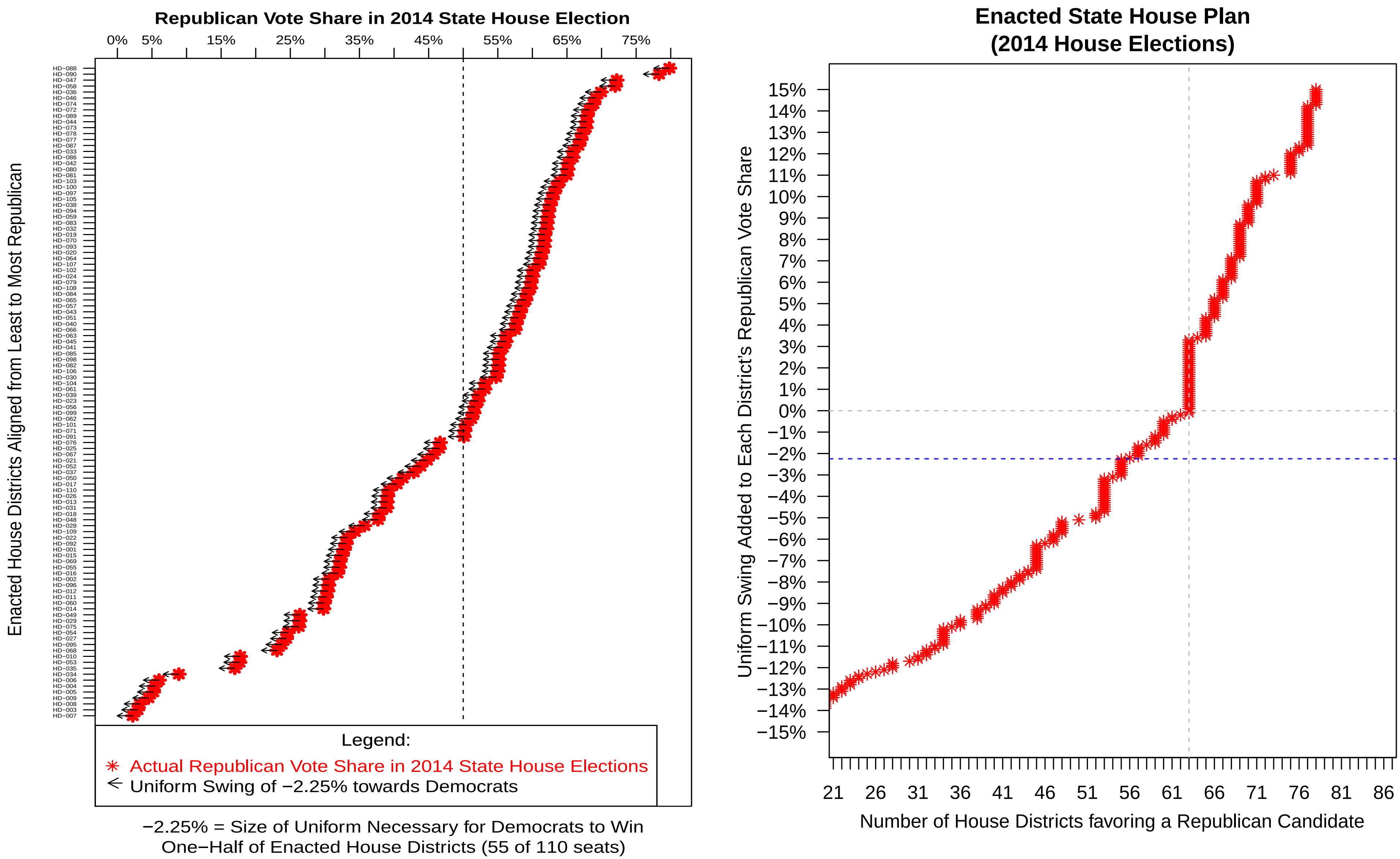
Appendix C, Figure C5:



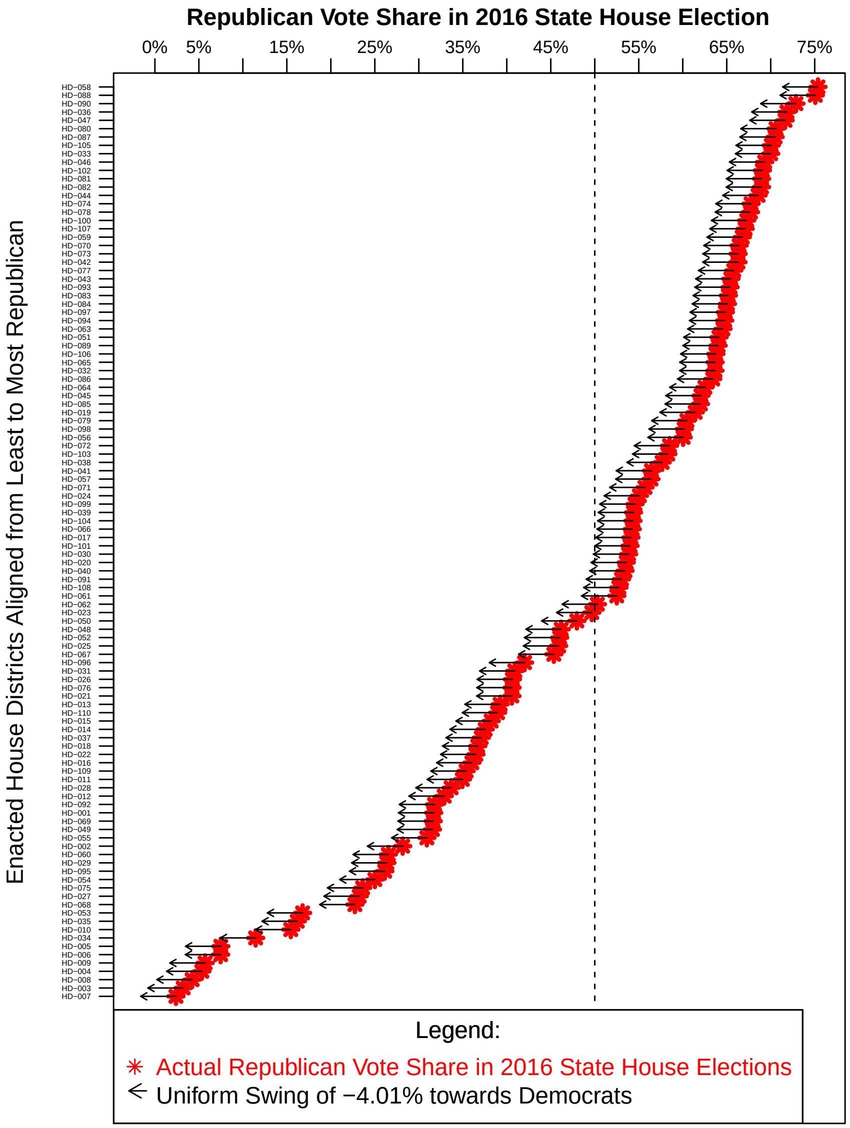
−1.04% = Size of Uniform Necessary for Democrats to Win
One−Half of Enacted House Districts (55 of 110 seats)



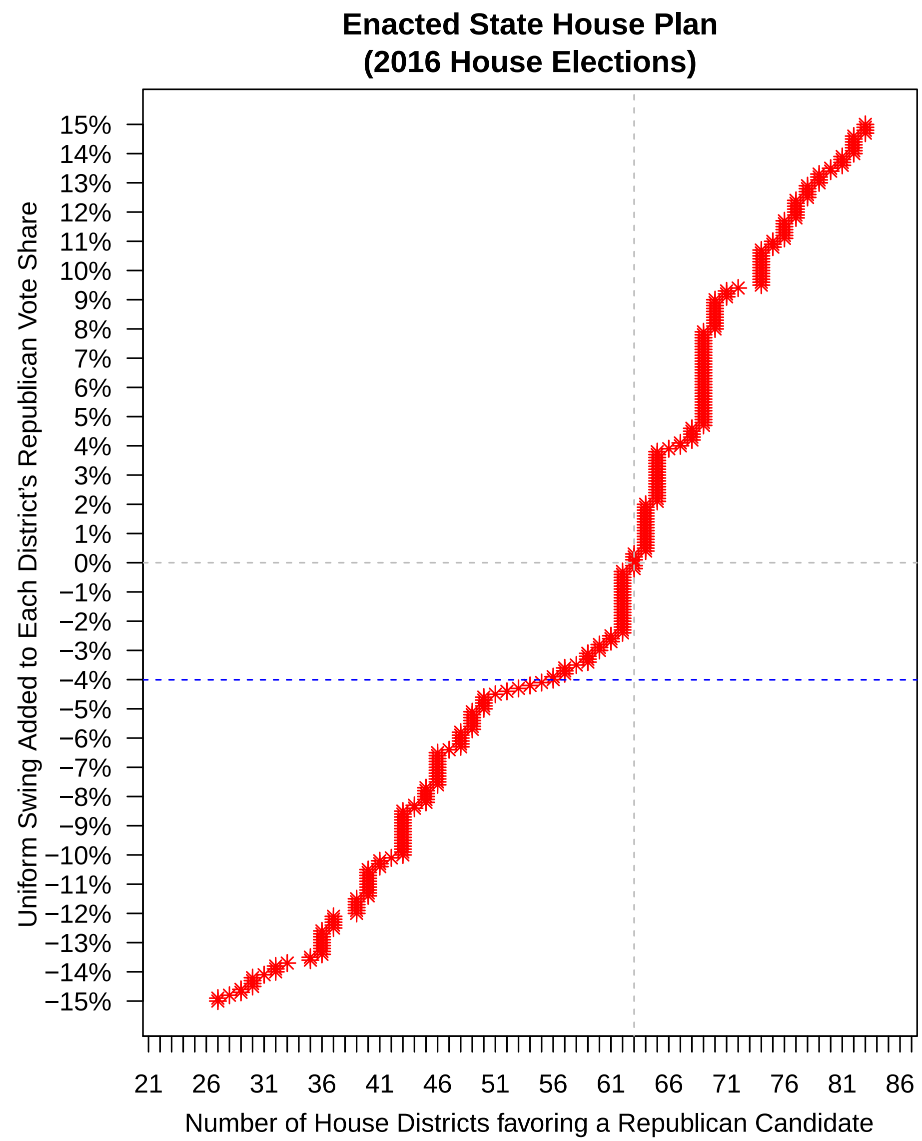
Appendix C, Figure C6:



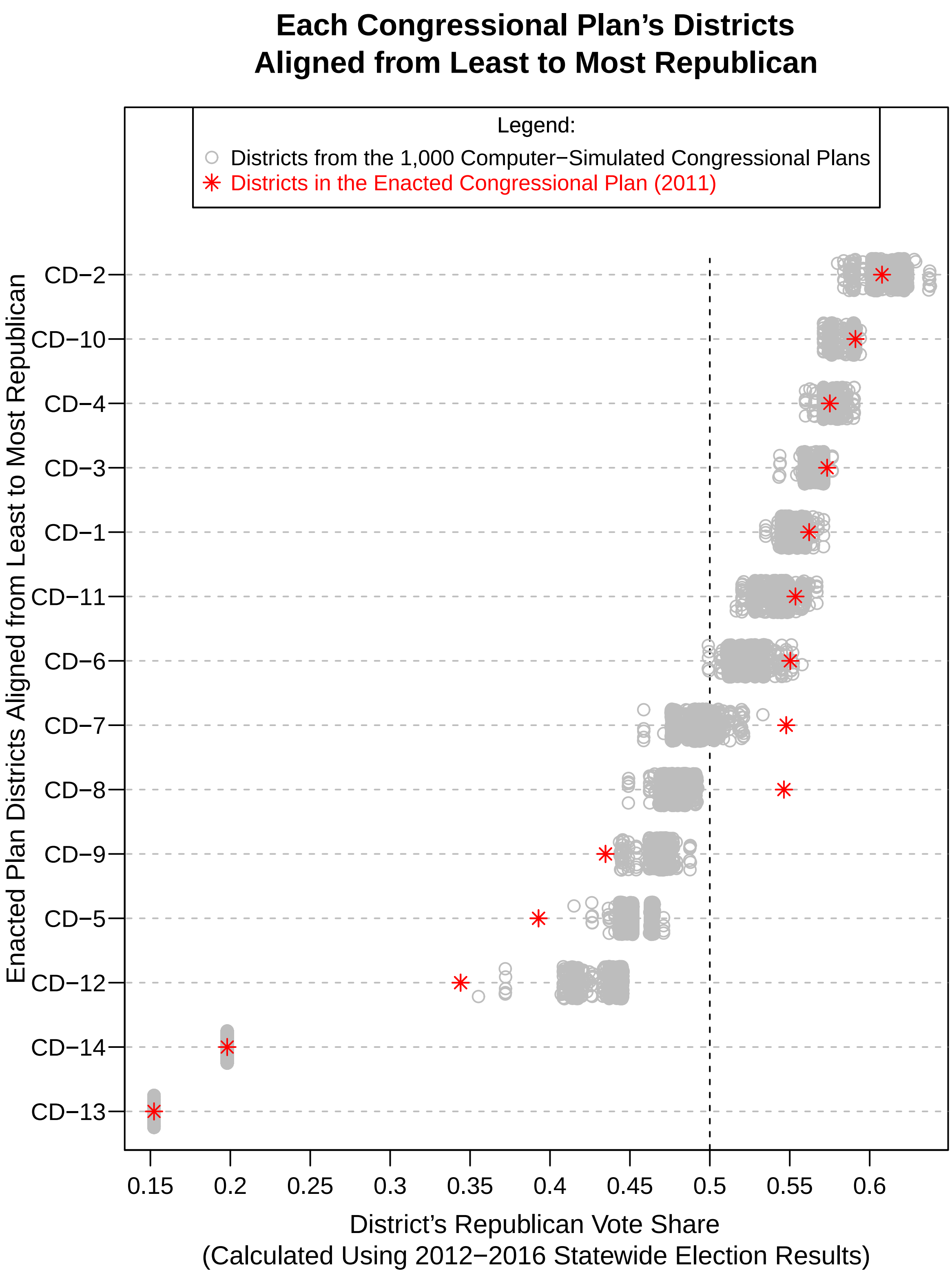
Appendix C, Figure C7:



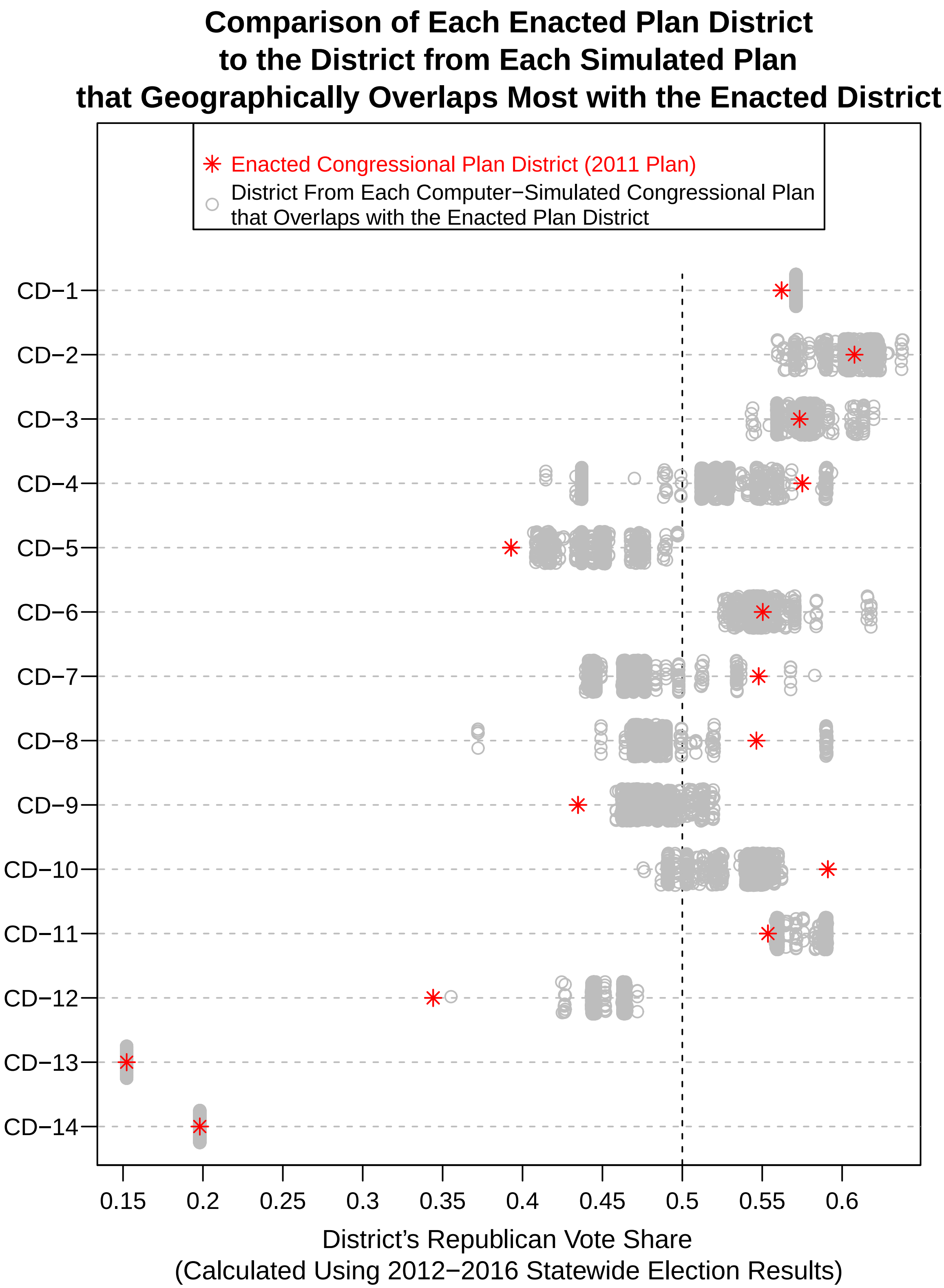
−4.01% = Size of Uniform Necessary for Democrats to Win
One−Half of Enacted House Districts (55 of 110 seats)



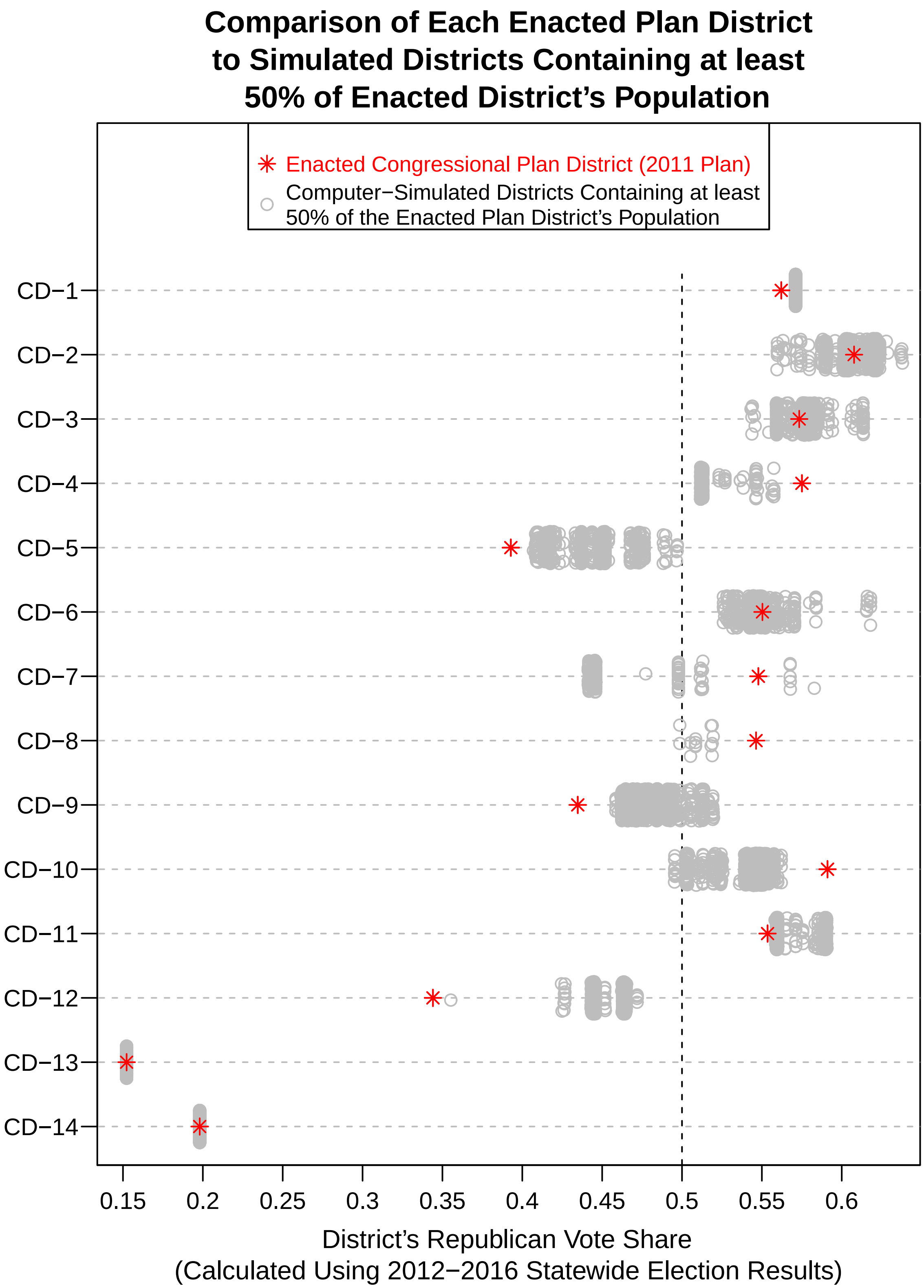
Appendix D1:


Each Congressional Plan's Districts
Aligned from Least to Most Republican
Legend:
Districts from the 1,000 Computer−Simulated Congressional Plans
Districts in the Enacted Congressional Plan (2011)
Enacted Plan Districts Aligned from Least to Most Republican
CD−2
CD−10
CD−4
CD−3
CD−1
CD−11
CD−6
CD−7
CD−8
CD−9
CD−5
CD−12
CD−14
CD−13
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

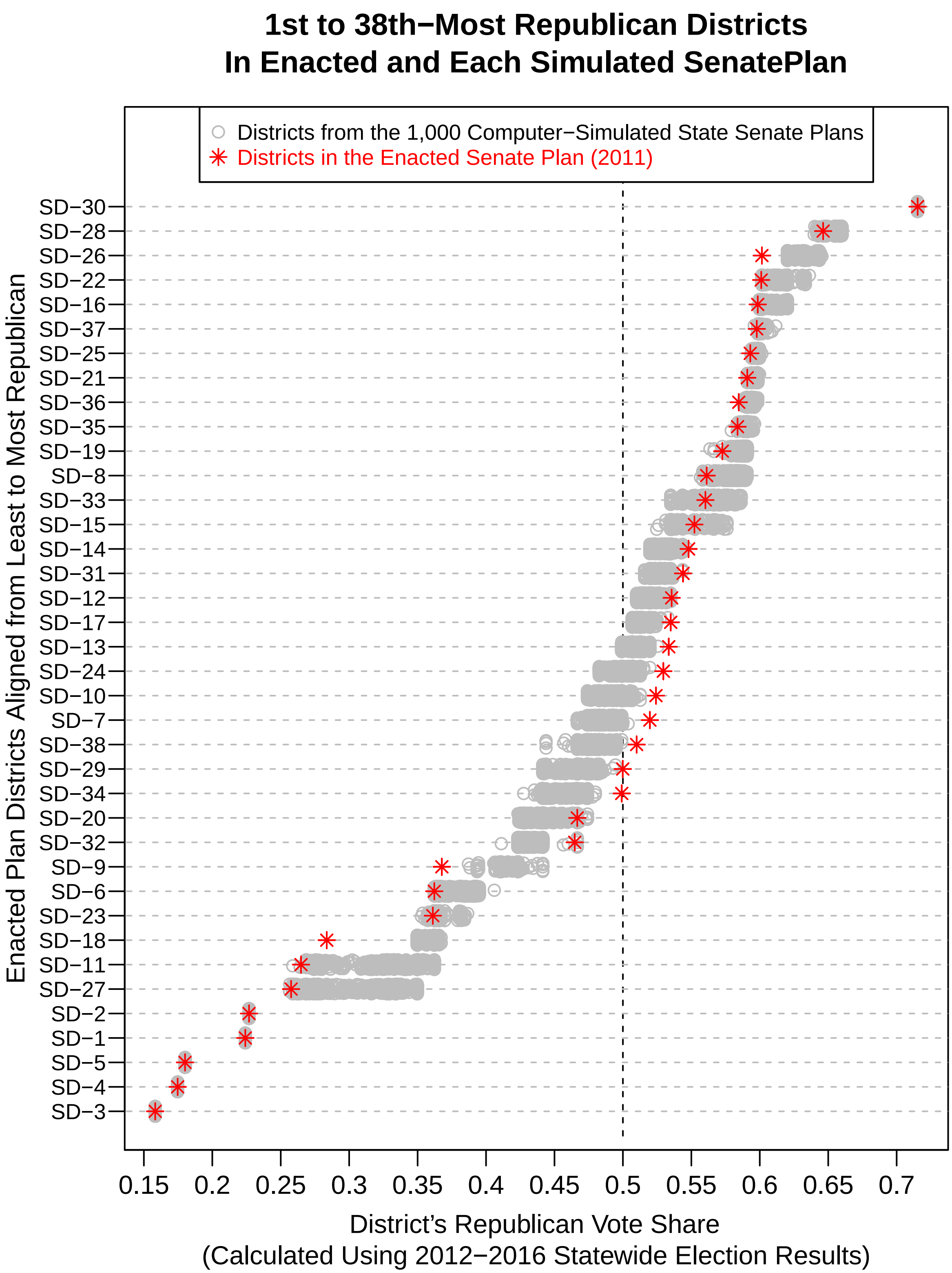
Appendix D2:


Comparison of Each Enacted Plan District
to the District from Each Simulated Plan
that Geographically Overlaps Most with the Enacted District
Enacted Congressional Plan District (2011 Plan)
District From Each Computer−Simulated Congressional Plan
that Overlaps with the Enacted Plan District
CD−1
CD−2
CD−3
CD−4
CD−5
CD−6
CD−7
CD−8
CD−9
CD−10
CD−11
CD−12
CD−13
CD−14
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

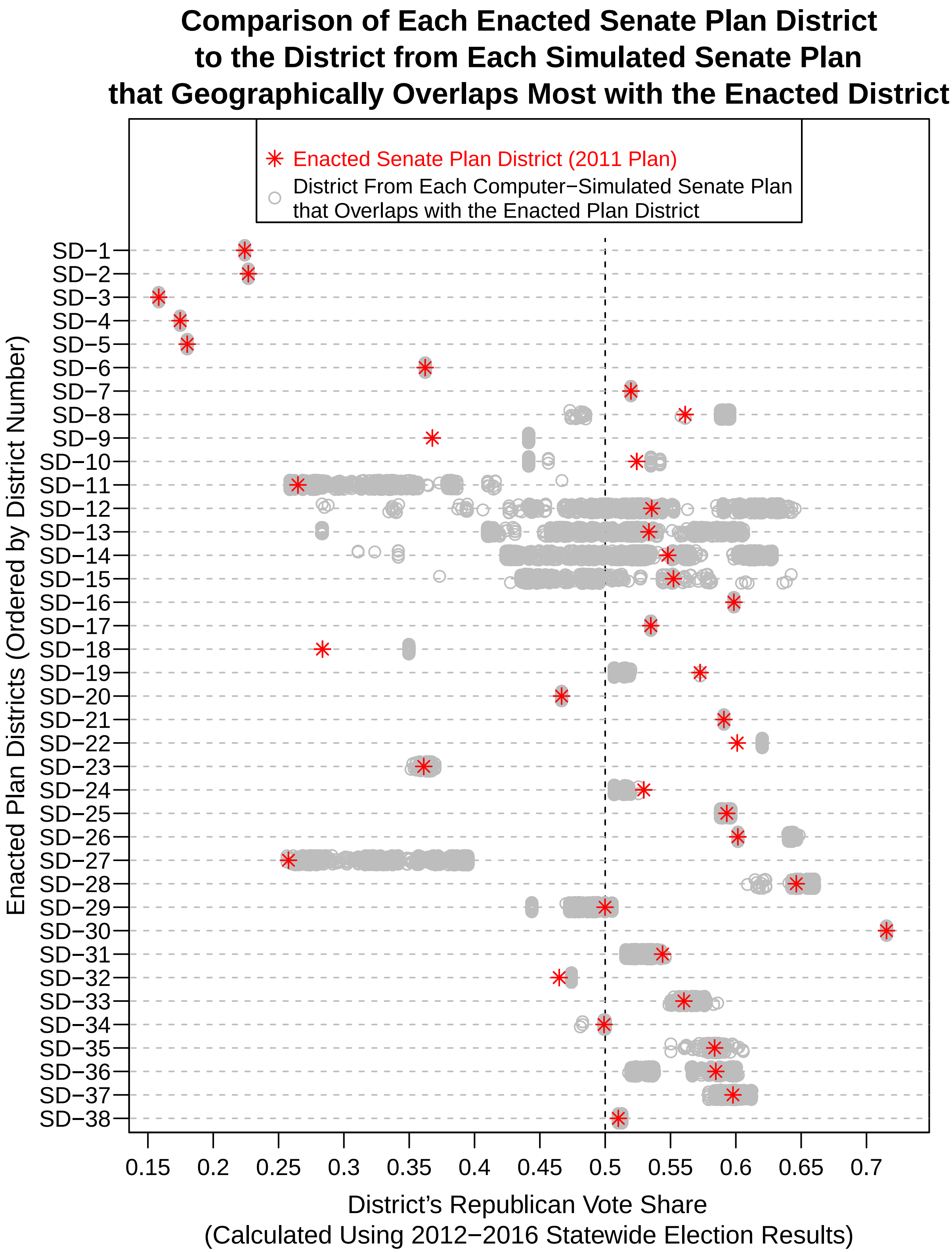
Appendix D3:


Comparison of Each Enacted Plan District
to Simulated Districts Containing at least
50% of Enacted District's Population
Enacted Congressional Plan District (2011 Plan)
Computer−Simulated Districts Containing at least 50% of the Enacted Plan District's Population
CD−1
CD−2
CD−3
CD−4
CD−5
CD−6
CD−7
CD−8
CD−9
CD−10
CD−11
CD−12
CD−13
CD−14
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

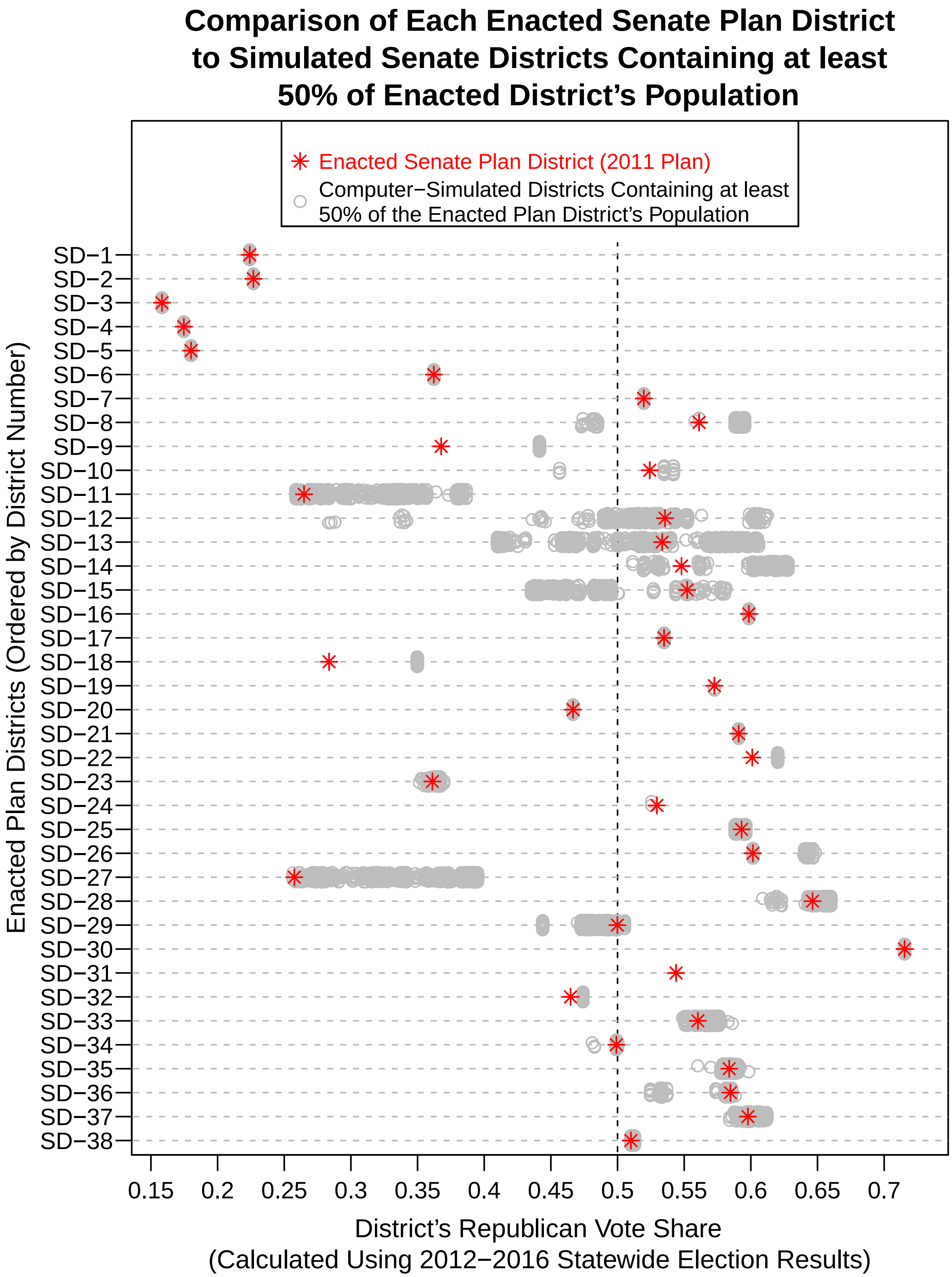
Appendix D4:


1st to 38th−Most Republican Districts
In Enacted and Each Simulated SenatePlan
Districts from the 1,000 Computer−Simulated State Senate Plans
Districts in the Enacted Senate Plan (2011)
Enacted Plan Districts Aligned from Least to Most Republican
SD−30
SD−28
SD−26
SD−22
SD−16
SD−37
SD−25
SD−21
SD−36
SD−35
SD−19
SD−8
SD−33
SD−15
SD−14
SD−31
SD−12
SD−17
SD−13
SD−24
SD−10
SD−7
SD−38
SD−29
SD−34
SD−20
SD−32
SD−9
SD−6
SD−23
SD−18
SD−11
SD−27
SD−2
SD−1
SD−5
SD−4
SD−3
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

Appendix D5:

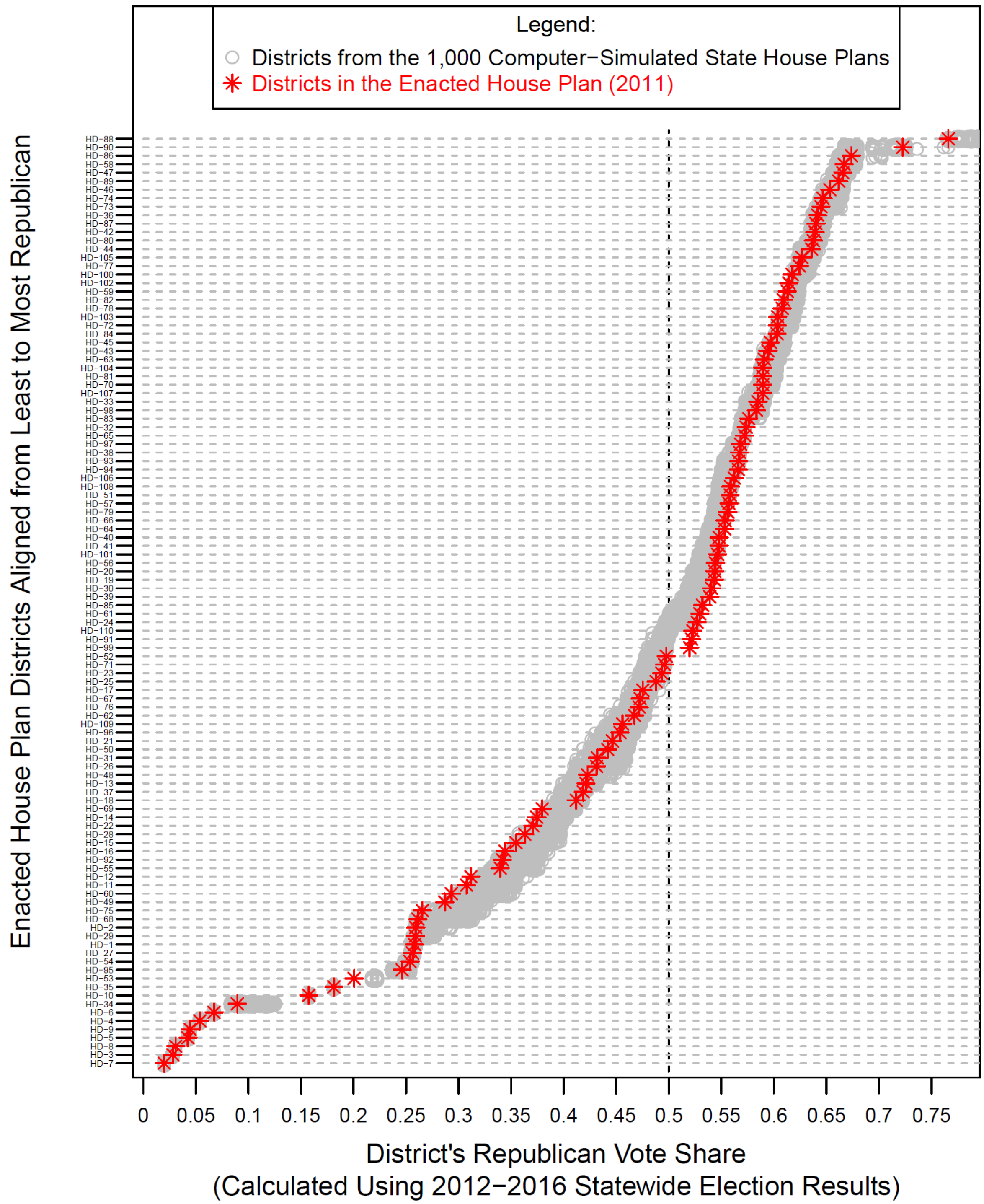

Comparison of Each Enacted Senate Plan District
to the District from Each Simulated Senate Plan
that Geographically Overlaps Most with the Enacted District
Enacted Senate Plan District (2011 Plan)
District From Each Computer−Simulated Senate Plan that Overlaps with the Enacted Plan District
SD−1
SD−2
SD−3
SD−4
SD−5
SD−6
SD−7
SD−8
SD−9
SD−10
SD−11
SD−12
SD−13
SD−14
SD−15
SD−16
SD−17
SD−18
SD−19
SD−20
SD−21
SD−22
SD−23
SD−24
SD−25
SD−26
SD−27
SD−28
SD−29
SD−30
SD−31
SD−32
SD−33
SD−34
SD−35
SD−36
SD−37
SD−38
Enacted Plan Districts (Ordered by District Number)
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

Appendix D6:

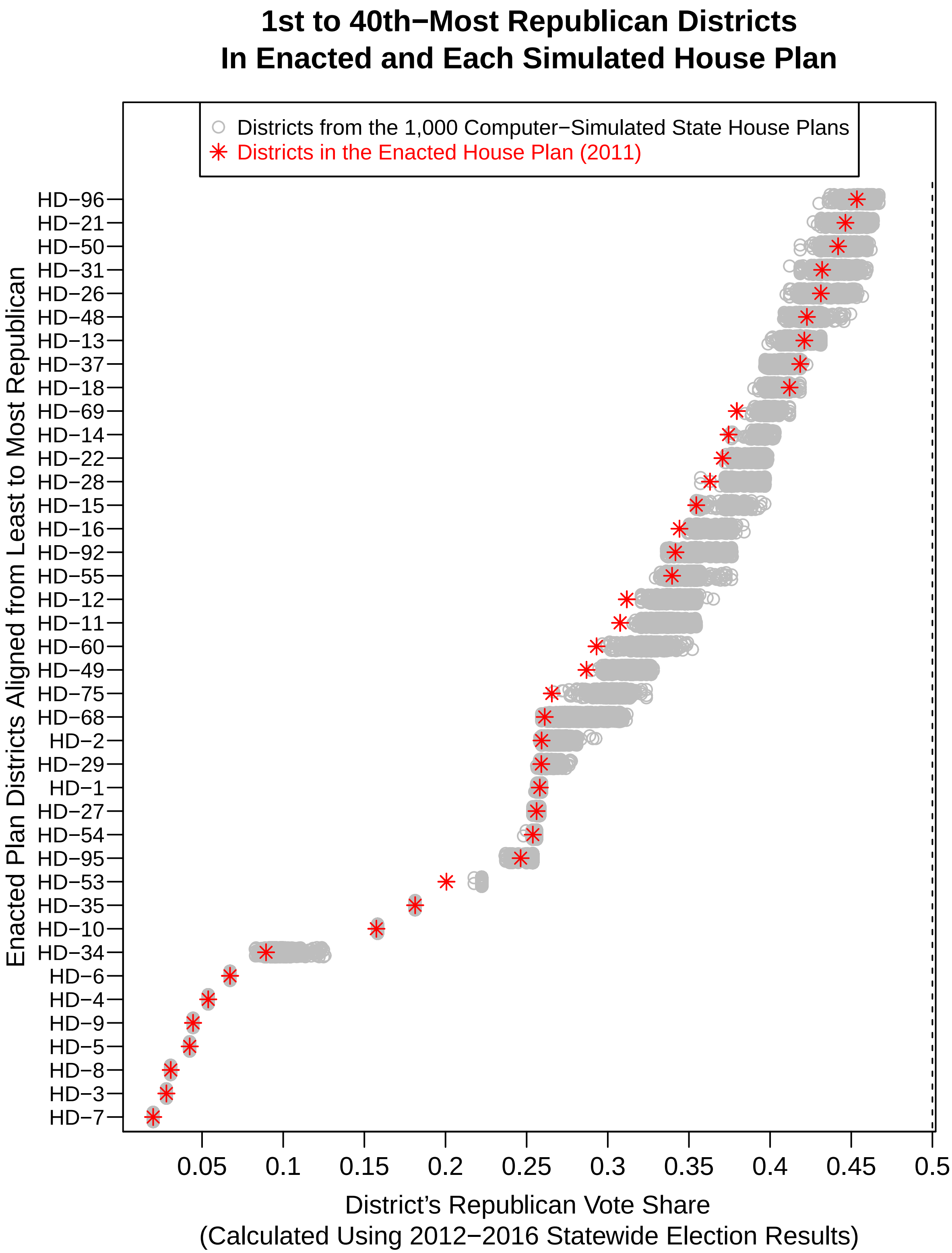

Comparison of Each Enacted Senate Plan District
to Simulated Senate Districts Containing at least
50% of Enacted District's Population
Enacted Senate Plan District (2011 Plan)
Computer−Simulated Districts Containing at least
50% of the Enacted Plan District's Population
SD−1
SD−2
SD−3
SD−4
SD−5
SD−6
SD−7
SD−8
SD−9
SD−10
SD−11
SD−12
SD−13
SD−14
SD−15
SD−16
SD−17
SD−18
SD−19
SD−20
SD−21
SD−22
SD−23
SD−24
SD−25
SD−26
SD−27
SD−28
SD−29
SD−30
SD−31
SD−32
SD−33
SD−34
SD−35
SD−36
SD−37
SD−38
Enacted Plan Districts (Ordered by District Number)
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
0.55
0.6
0.65
0.7
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

Appendix D7:

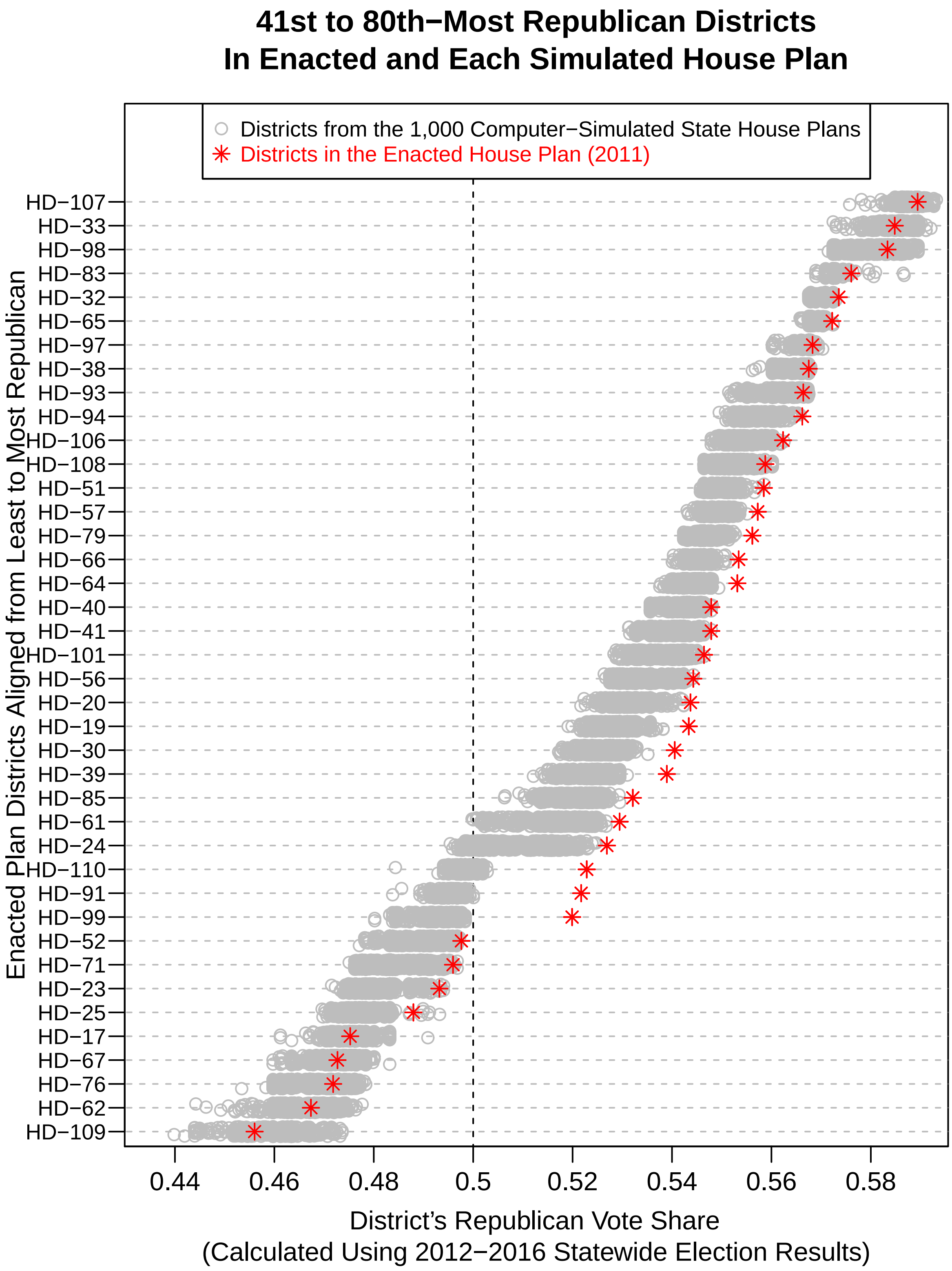
Each State House Plan's Districts Aligned from Least to Most Republican



Appendix D8:


1st to 40th−Most Republican Districts
In Enacted and Each Simulated House Plan
Districts from the 1,000 Computer−Simulated State House Plans
Districts in the Enacted House Plan (2011)
Enacted Plan Districts Aligned from Least to Most Republican
HD−96
HD−21
HD−50
HD−31
HD−26
HD−48
HD−13
HD−37
HD−18
HD−69
HD−14
HD−22
HD−28
HD−15
HD−16
HD−92
HD−55
HD−12
HD−11
HD−60
HD−49
HD−75
HD−68
HD−2
HD−29
HD−1
HD−27
HD−54
HD−95
HD−53
HD−35
HD−10
HD−34
HD−6
HD−4
HD−9
HD−5
HD−8
HD−3
HD−7
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

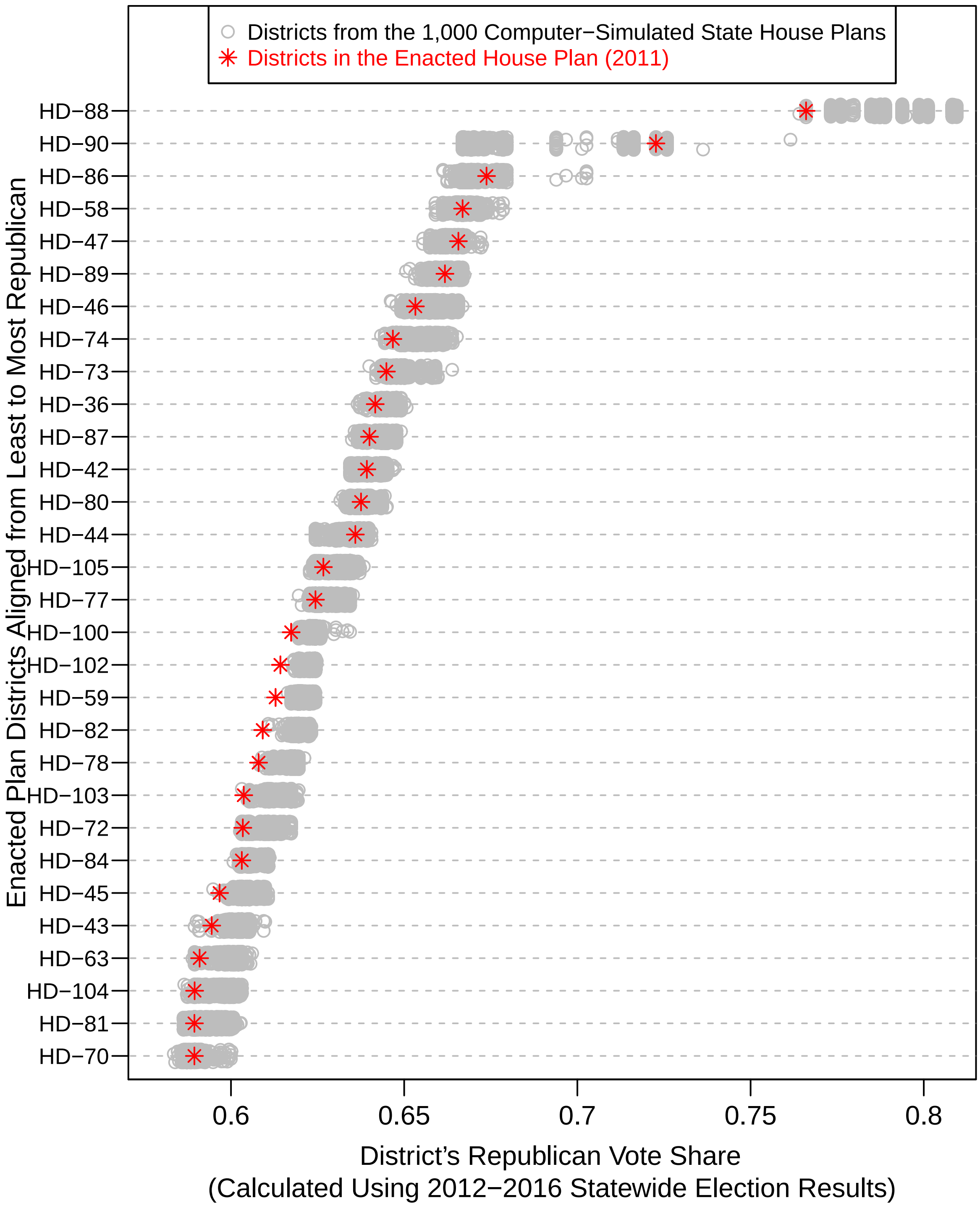
Appendix D9:



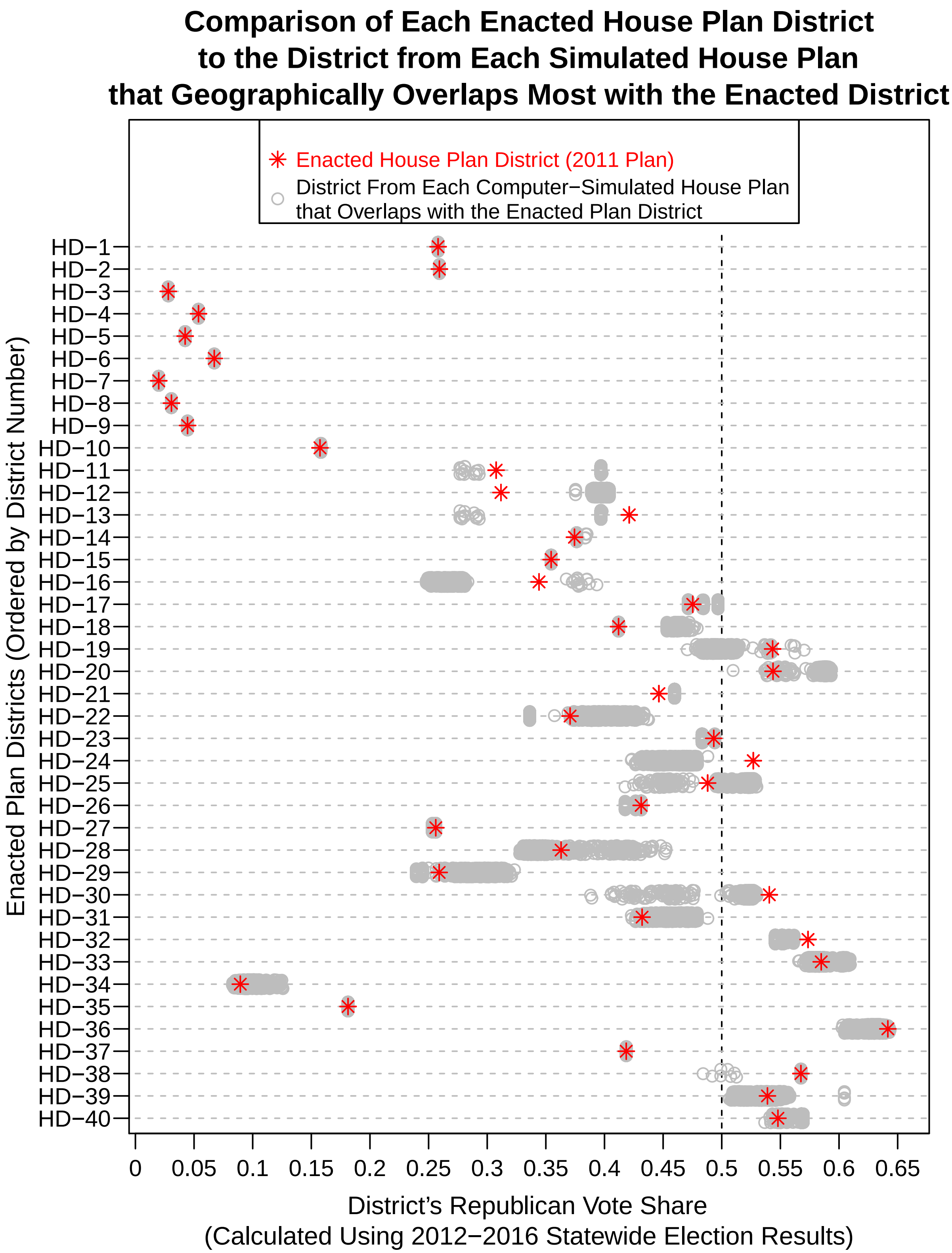
41st to 80th−Most Republican Districts
In Enacted and Each Simulated House Plan
Districts from the 1,000 Computer−Simulated State House Plans
Districts in the Enacted House Plan (2011)
HD−107
HD−33
HD−98
HD−83
HD−32
HD−65
HD−97
HD−38
HD−93
HD−94
HD−106
HD−108
HD−51
HD−57
HD−79
HD−66
HD−64
HD−40
HD−41
HD−101
HD−56
HD−20
HD−19
HD−30
HD−39
HD−85
HD−61
HD−24
HD−110
HD−91
HD−99
HD−52
HD−71
HD−23
HD−25
HD−17
HD−67
HD−76
HD−62
HD−109
Enacted Plan Districts Aligned from Least to Most Republican
0.44
0.46
0.48
0.5
0.52
0.54
0.56
0.58
District's Republican Vote Share
(Calculated Using 2012−2016 Statewide Election Results)

Appendix D10:

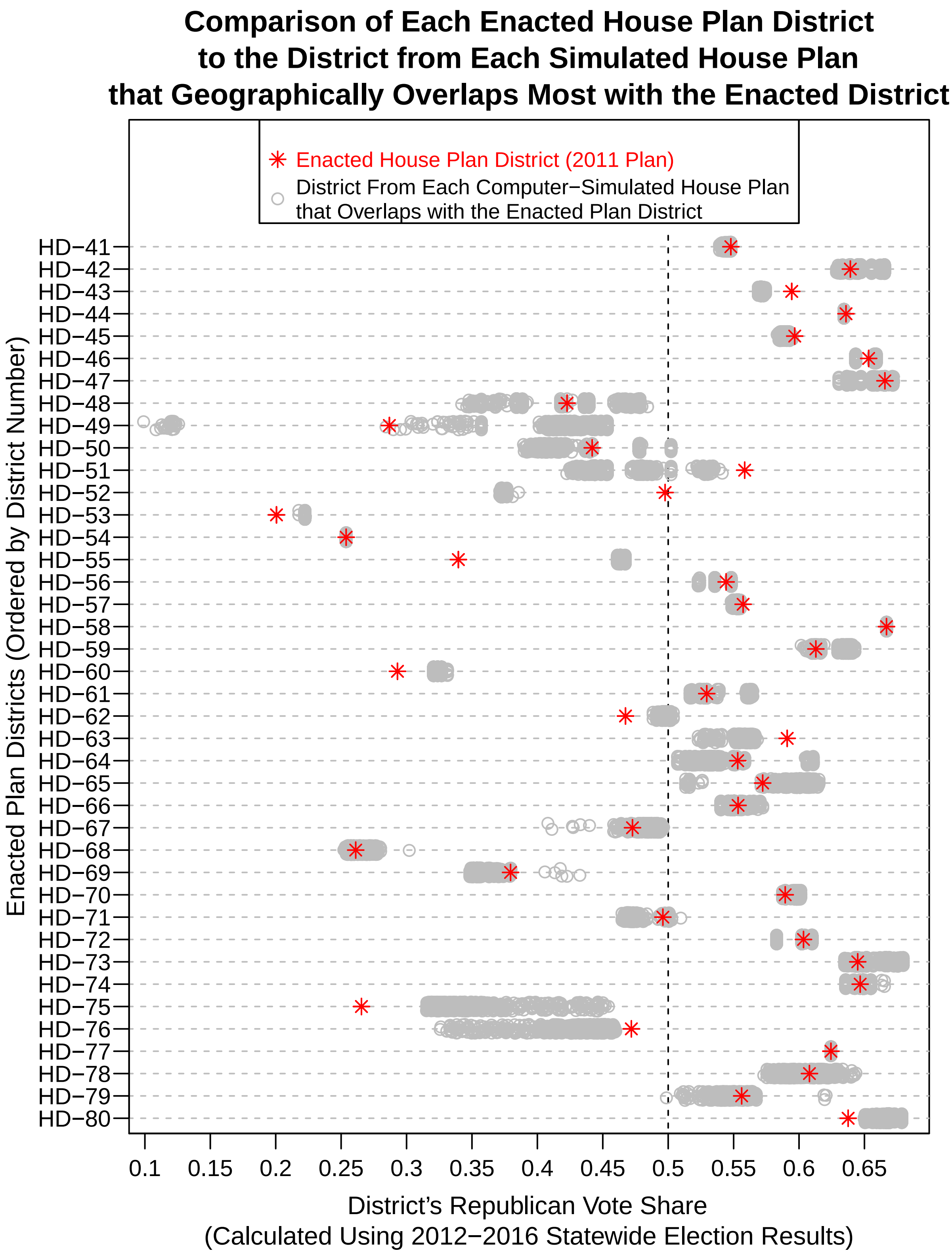
81st to 110th−Most Republican Districts In Enacted and Each Simulated House Plan



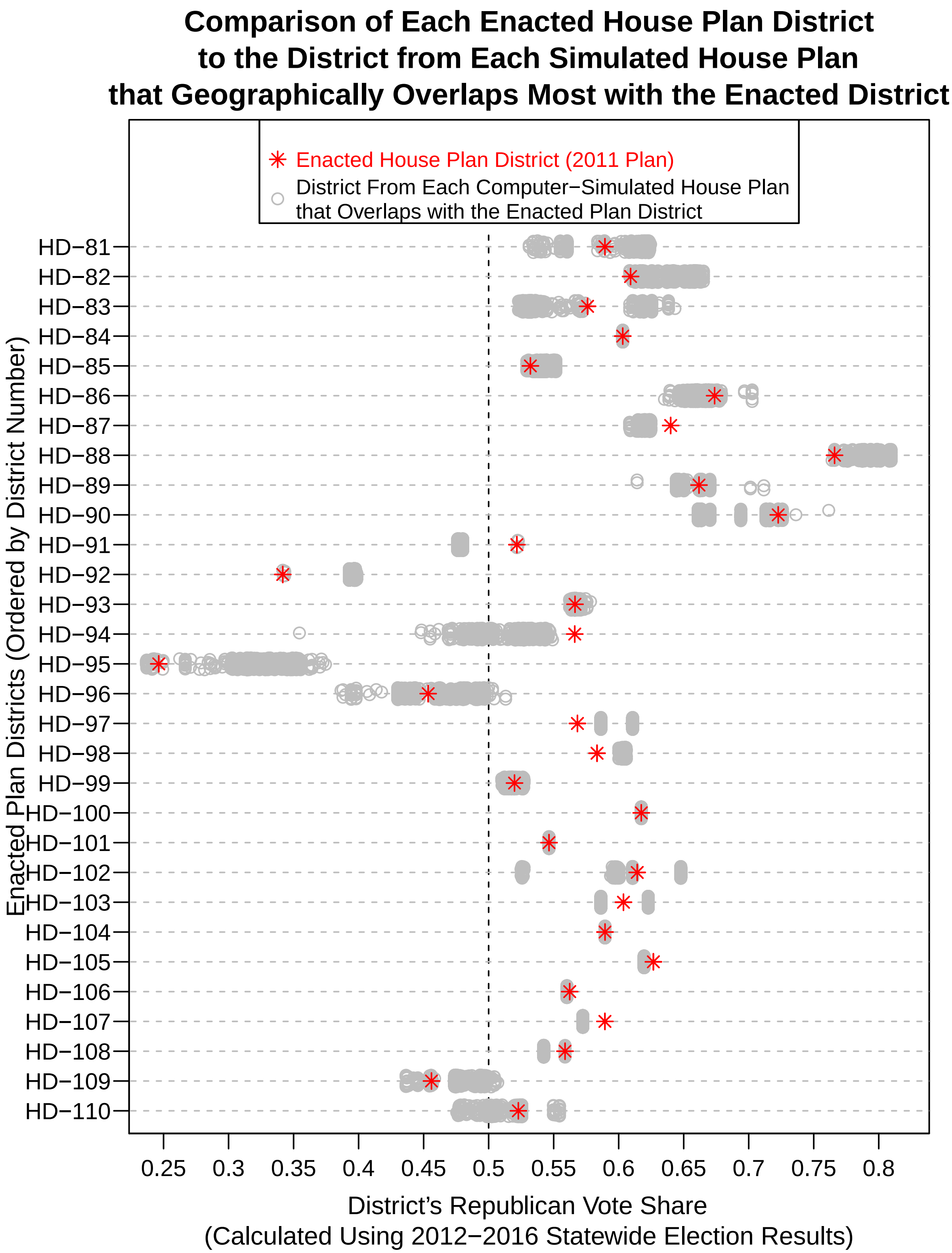
Appendix D11:



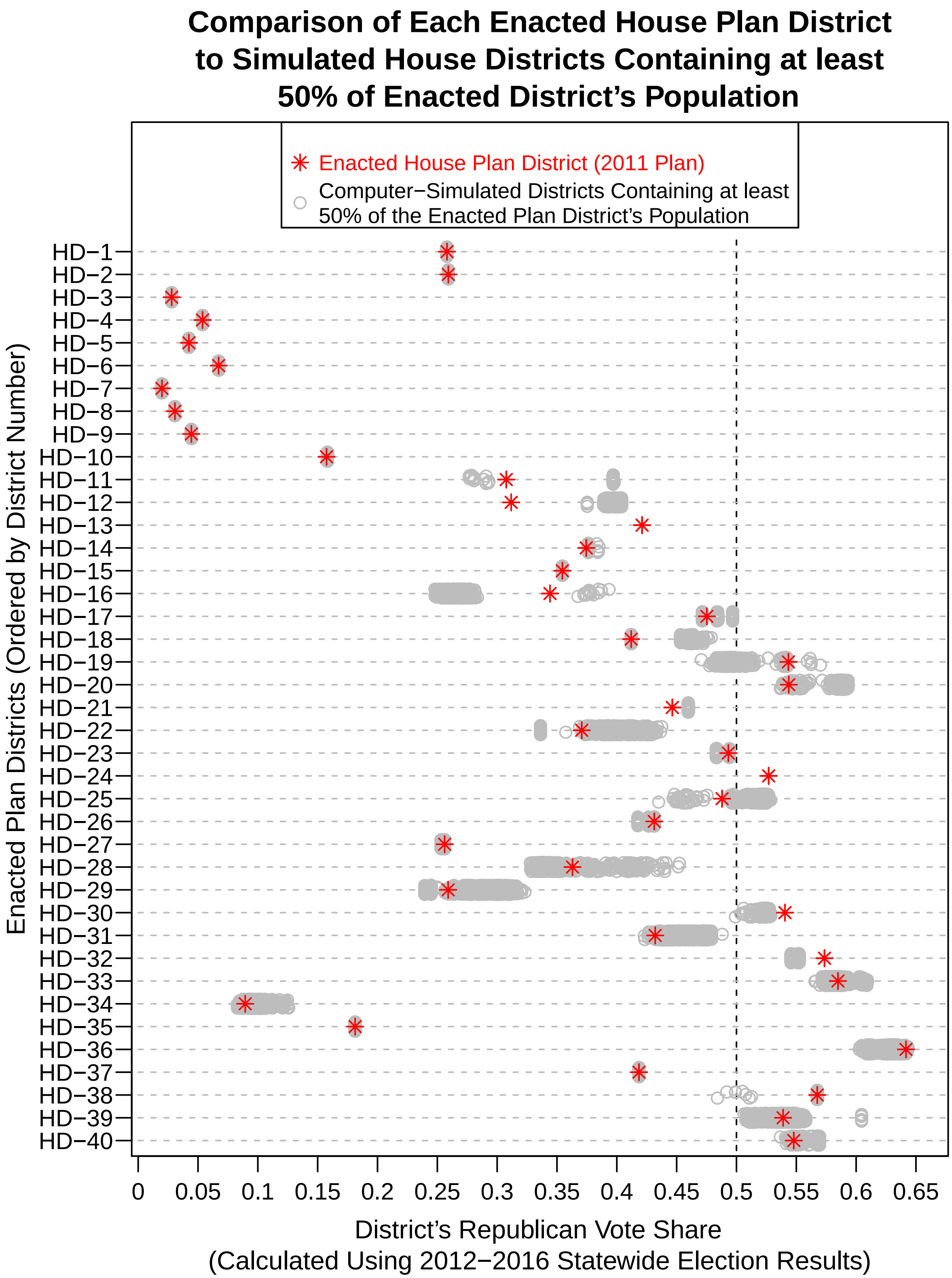
Appendix D12:



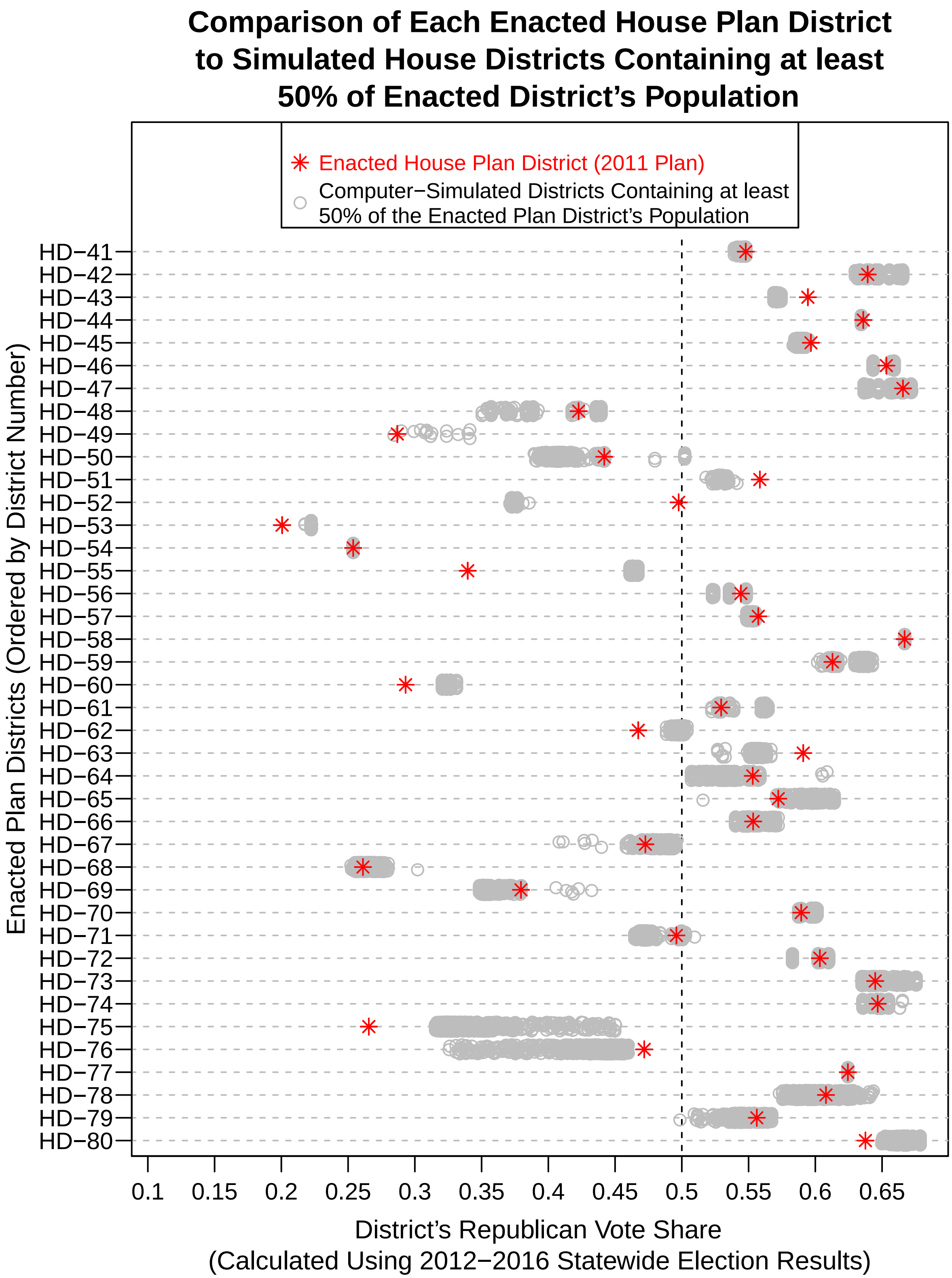
Appendix D13:



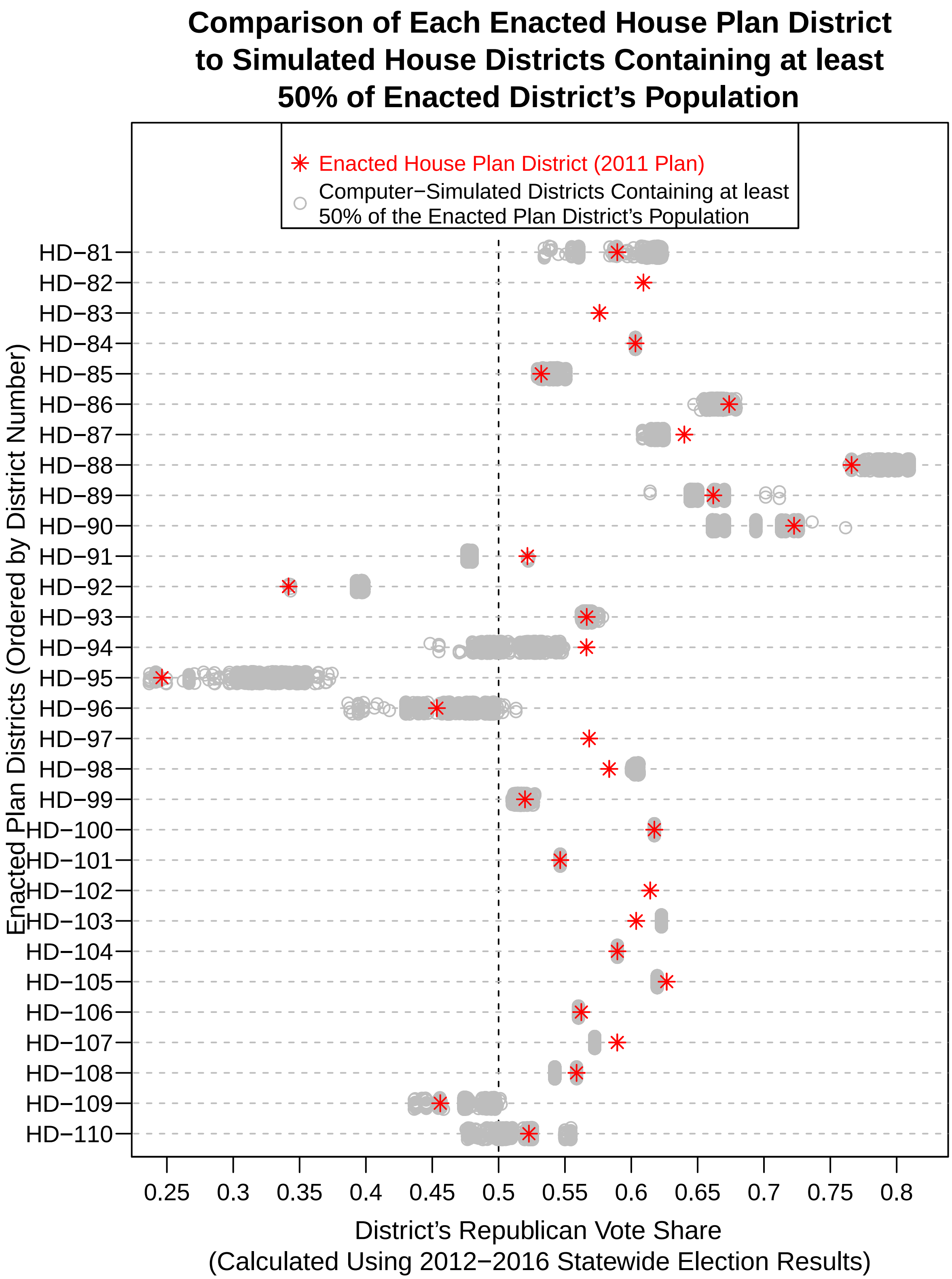
Appendix D14:



Appendix D15:



Appendix D16:



Jowei Chen
Curriculum Vitae

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Academic Positions:
Associate Professor (2015-present), Assistant Professor (2009-2015), Department of Political Science, University of Michigan.
Faculty Associate, Center for Political Studies, University of Michigan, 2009 – Present.
W. Glenn Campbell and Rita Ricardo-Campbell National Fellow, Hoover Institution, Stanford University, 2013.
Principal Investigator and Senior Research Fellow, Center for Governance and Public Policy Research, Willamette University, 2013 – Present.

Education:
Ph.D., Political Science, Stanford University (June 2009)
M.S., Statistics, Stanford University (January 2007)
B.A., Ethics, Politics, and Economics, Yale University (May 2004)

Publications:

Chen, Jowei and Neil Malhotra. 2007. "The Law of k/n: The Effect of Chamber Size on Government Spending in Bicameral Legislatures."
American Political Science Review. **101(4): 657-676.**

Chen, Jowei, 2010. "The Effect of Electoral Geography on Pork Barreling in Bicameral Legislatures."
American Journal of Political Science. **54(2): 301-322.**

Chen, Jowei, 2013. "Voter Partisanship and the Effect of Distributive Spending on Political Participation."
American Journal of Political Science. **57(1): 200-217.**

Chen, Jowei and Jonathan Rodden, 2013. "Unintentional Gerrymandering: Political Geography and Electoral Bias in Legislatures"
Quarterly Journal of Political Science, **8(3): 239-269.**

Bradley, Katharine and Jowei Chen, 2014. "Participation Without Representation? Senior Opinion, Legislative Behavior, and Federal Health Reform."
Journal of Health Politics, Policy and Law. **39(2), 263-293.**

Chen, Jowei and Tim Johnson, 2015. "Federal Employee Unionization and Presidential Control of the Bureaucracy: Estimating and Explaining Ideological Change in Executive Agencies."
Journal of Theoretical Politics, **Volume 27, No. 1: 151-174.**

Bonica, Adam, Jowei Chen, and Tim Johnson, 2015. "Senate Gate-Keeping, Presidential Staffing of 'Inferior Offices' and the Ideological Composition of Appointments to the Public Bureaucracy."
Quarterly Journal of Political Science. Volume 10, No. 1: 5-40.

Chen, Jowei and Jonathan Rodden, 2015. "Redistricting Simulations and the Detection Cutting through the Thicket: of Partisan Gerrymanders."
Election Law Journal. Volume 14, Number 4: 331-345.

Chen, Jowei and David Cottrell, 2016. "Evaluating Partisan Gains from Congressional Gerrymandering: Using Computer Simulations to Estimate the Effect of Gerrymandering in the U.S. House."
Electoral Studies. Volume 44 (December 2016): 329-340.

Chen, Jowei, 2017. "Analysis of Computer-Simulated Districting Maps for the Wisconsin State Assembly."
Forthcoming 2017, _Election Law Journal_.

Non-Peer-Reviewed Publication:

Chen, Jowei and Tim Johnson. 2017. "Political Ideology in the Bureaucracy."
Global Encyclopedia of Public Administration, Public Policy, and Governance.

Chen, Jowei. October 4, 2017. Time Magazine Op-Ed.
http://time.com/4965673/wisconsin-supreme-court-gerrymandering-research/

Chen, Jowei and Jonathan Rodden. January 2014. New York Times Op-Ed.
https://www.nytimes.com/2014/01/26/opinion/sunday/its-the-geography-stupid.html

Research Grants:

Principal Investigator. National Science Foundation Grant SES-1459459, September 2015 – August 2018 ($165,008). "The Political Control of U.S. Federal Agencies and Bureaucratic Political Behavior."

"Economic Disparity and Federal Investments in Detroit," (with Brian Min) 2011. Graham Institute, University of Michigan ($30,000).

"The Partisan Effect of OSHA Enforcement on Workplace Injuries," (with Connor Raso) 2009. John M. Olin Law and Economics Research Grant ($4,410).

Invited Talks:

September, 2011. University of Virginia, American Politics Workshop.
October 2011. Massachusetts Institute of Technology, American Politics Conference.
January 2012. University of Chicago, Political Economy/American Politics Seminar.
February 2012. Harvard University, Positive Political Economy Seminar.
September 2012. Emory University, Political Institutions and Methodology Colloquium.
November 2012. University of Wisconsin, Madison, American Politics Workshop.
September 2013. Stanford University, Graduate School of Business, Political Economy Workshop.
February 2014. Princeton University, Center for the Study of Democratic Politics Workshop.
November 2014. Yale University, American Politics and Public Policy Workshop.

December 2014. American Constitution Society for Law & Policy Conference: Building the Evidence to Win Voting Rights Cases.
February 2015. University of Rochester, American Politics Working Group.
March 2015. Harvard University, Voting Rights Act Workshop.
May 2015. Harvard University, Conference on Political Geography.
Octoer 2015. George Washington University School of Law, Conference on Redistricting Reform.
September 2016. Harvard University Center for Governmental and International Studies, Voting Rights Institute Conference.
March 2017. Duke University, Sanford School of Public Policy, Redistricting Reform Conference.
October 2017. Willamette University, Center for Governance and Public Policy Research
October 2017, University of Wisconsin, Madison. Geometry of Redistricting Conference.

Conference Service:

Section Chair, 2017 APSA (Chicago, IL), Political Methodology Section
Discussant, 2014 Political Methodology Conference (University of Georgia)
Section Chair, 2012 MPSA (Chicago, IL), Political Geography Section.
Discussant, 2011 MPSA (Chicago, IL) "Presidential-Congressional Interaction."
Discussant, 2008 APSA (Boston, MA) "Congressional Appropriations."
Chair and Discussant, 2008 MPSA (Chicago, IL) "Distributive Politics: Parties and Pork."

Conference Presentations and Working Papers:

"Ideological Representation of Geographic Constituencies in the U.S. Bureaucracy," (with Tim Johnson). 2017 APSA.

"Incentives for Political versus Technical Expertise in the Public Bureaucracy," (with Tim Johnson). 2016 APSA.

"Black Electoral Geography and Congressional Districting: The Effect of Racial Redistricting on Partisan Gerrymandering". 2016 Annual Meeting of the Society for Political Methodology (Rice University)

"Racial Gerrymandering and Electoral Geography." Working Paper, 2016.

"Does Deserved Spending Win More Votes? Evidence from Individual-Level Disaster Assistance," (with Andrew Healy). 2014 APSA.

"The Geographic Link Between Votes and Seats: How the Geographic Distribution of Partisans Determines the Electoral Responsiveness and Bias of Legislative Elections," (with David Cottrell). 2014 APSA.

"Gerrymandering for Money: Drawing districts with respect to donors rather than voters." 2014 MPSA.

"Constituent Age and Legislator Responsiveness: The Effect of Constituent Opinion on the Vote for Federal Health Reform." (with Katharine Bradley) 2012 MPSA.

"Voter Partisanship and the Mobilizing Effect of Presidential Advertising." (with Kyle Dropp) 2012 MPSA.

"Recency Bias in Retrospective Voting: The Effect of Distributive Benefits on Voting Behavior." (with Andrew Feher) 2012 MPSA.

"Estimating the Political Ideologies of Appointed Public Bureaucrats," (with Adam Bonica and Tim Johnson) 2012 Annual Meeting of the Society for Political Methodology (University of North Carolina)

"Tobler's Law, Urbanization, and Electoral Bias in Florida." (with Jonathan Rodden) 2010 Annual Meeting of the Society for Political Methodology (University of Iowa)

"Unionization and Presidential Control of the Bureaucracy" (with Tim Johnson) 2011 MPSA.

"Estimating Bureaucratic Ideal Points with Federal Campaign Contributions" 2010 APSA. (Washington, DC).

"The Effect of Electoral Geography on Pork Spending in Bicameral Legislatures," Vanderbilt University Conference on Bicameralism, 2009.

"When Do Government Benefits Influence Voters' Behavior? The Effect of FEMA Disaster Awards on US Presidential Votes," 2009 APSA (Toronto, Canada).

"Are Poor Voters Easier to Buy Off?" 2009 APSA (Toronto, Canada).

"Credit Sharing Among Legislators: Electoral Geography's Effect on Pork Barreling in Legislatures," 2008 APSA (Boston, MA).

"Buying Votes with Public Funds in the US Presidential Election," Poster Presentation at the 2008 Annual Meeting of the Society for Political Methodology (University of Michigan).

"The Effect of Electoral Geography on Pork Spending in Bicameral Legislatures," 2008 MPSA.

"Legislative Free-Riding and Spending on Pure Public Goods," 2007 MPSA (Chicago, IL).

"Free Riding in Multi-Member Legislatures," (with Neil Malhotra) 2007 MPSA (Chicago, IL).

"The Effect of Legislature Size, Bicameralism, and Geography on Government Spending: Evidence from the American States," (with Neil Malhotra) 2006 APSA (Philadelphia, PA).

Reviewer Service:

American Journal of Political Science
American Political Science Review
Journal of Politics
Quarterly Journal of Political Science
American Politics Research
Legislative Studies Quarterly
State Politics and Policy Quarterly
Journal of Public Policy
Journal of Empirical Legal Studies
Political Behavior
Political Research Quarterly

Political Analysis
Public Choice
Applied Geography